Electronics & Technology Today

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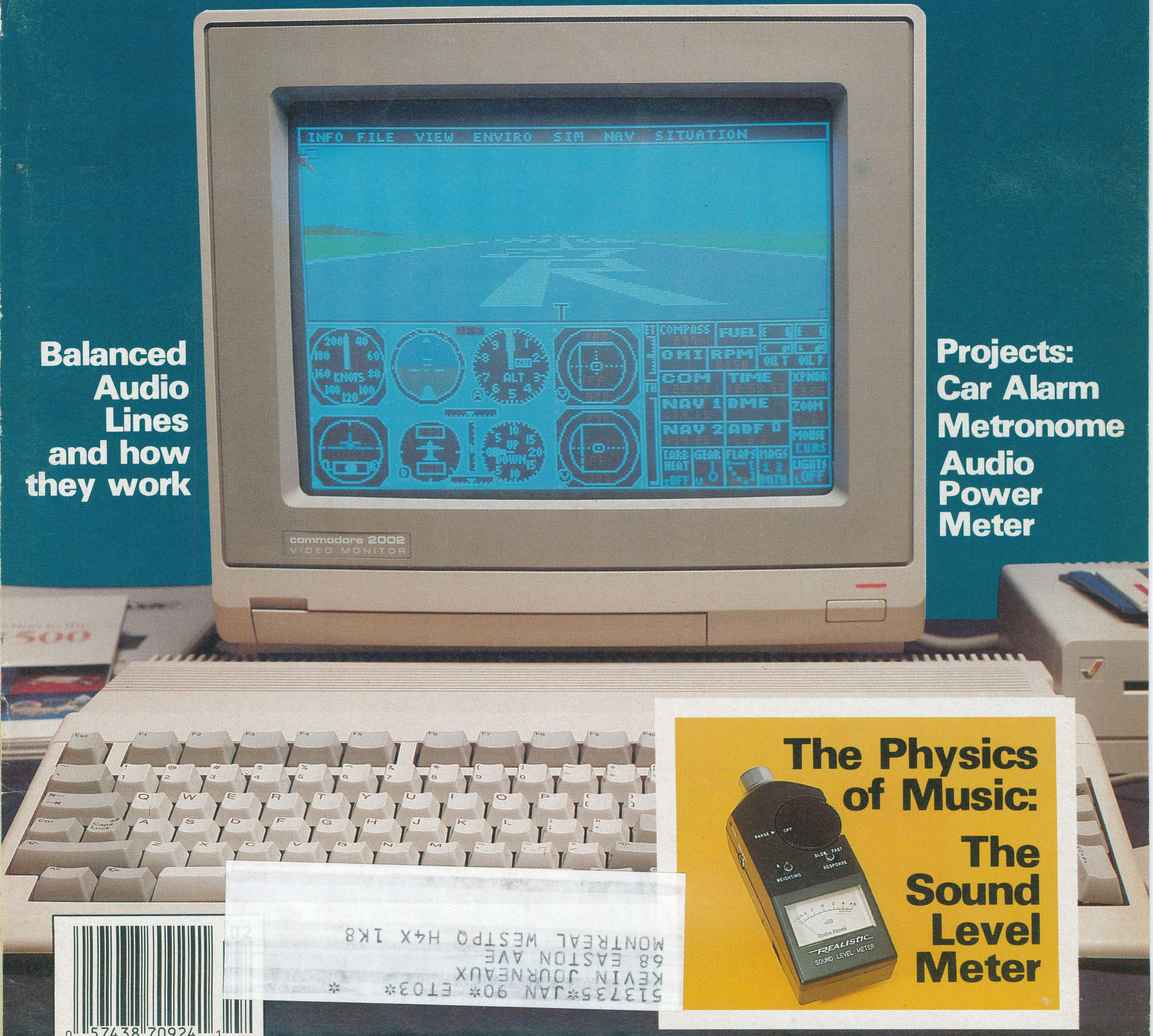
Canada's Magazine for High-tech Discovery

February 1988

The Amiga 500
Low Cost 32 bit computing



INFO FILE VIEW ENVIRO SIM NAV SITUATION
commodore 2002
VIDEO MONITOR
REALISTIC
SOUND LEVEL METER

Balanced Audio Lines and how they work

Projects:
Car Alarm
Metronome
Audio Power Meter

The Physics of Music: The Sound Level Meter

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The BES

IBM PC, XT and AT Compatibles Des

Microcomputer Speed Comparison
BEST AVX-386

BEST COMPACT 286

BEST COMPACT 86

BEST AVX-386

Basic System, Standard Features • MS DOS and UNIX Compatible • Based on 32 bit INTEL 80386 Microprocessor • Phoenix BIOS • Overall AT compatibility with significant additional features **Software Selectable Speed** • 16MHz or 8MHz **Disk Storage: two Floppy 5 1/4 inch diskette drives** • Drive A: 1.2 Megabytes capacity • Drive B: 360 Kilobytes capacity **Memory Capacity** • 2 Megabytes of RAM or • 8 Megabytes of RAM **Standard Peripheral Interfaces** • One serial interface • Parallel Printer Interface • Game/Joystick port • AT Compatible Real Time Clock/Calendar with Battery Backup • Hardware Reset switch • 10 expansion slots: 6 IBM AT compatible expansion slots; 4 IBM PC compatible expansion slots **Power Supply** • 200 watt total power, 90 to 132 VAC-50/60HZ, 198 to 264 VAC-50/60HZ • Switched and fused Auxilary power connector

BEST COMPACT 286

Basic System, Standard Features • IBM AT Compatible • Based on 16 bit INTEL 80286 Microprocessor • Phoenix BIOS • 8MHz system clock speed **Disk Storage: one Floppy 5 1/4 inch diskette drive** • Drive A: 360 Kilobytes capacity **Memory Capacity** • 640 Kilobytes of RAM **Standard Peripheral Interfaces** • AT Compatible Real Time Clock/Calendar with Battery Backup • Hardware Reset switch • 7 expansion Slots: 2 IBM PC compatible expansion slots; 5 IBM AT compatible expansion slots **Power supply** • 130 watt total power, 90 to 132 VAC-50/60HZ, 198 to 264 VAC-50/60HZ • Switched and fused Auxiliary power connector

BEST COMPACT 86

Basic System, Standard Features • IBM PC/XT Compatible • Based on 16 bit INTEL 8086-2 Microprocessor • Phoenix BIOS **Hardware Selectable Speed** • 8MHz or 4.77 MHz **Disk Storage: one Floppy 5 1/4 inch diskette drive** • Drive A: 360 Kilobytes capacity **Memory Capacity** • 256 Kilobytes of RAM **Standard Peripheral Interfaces** • Hardware Reset switch • 7 IBM PC/XT compatible expansion slots **Power Supply** 130 watt total power, 90 to 132 VAC-50/60HZ, 198 to 264 VAC-50HZ

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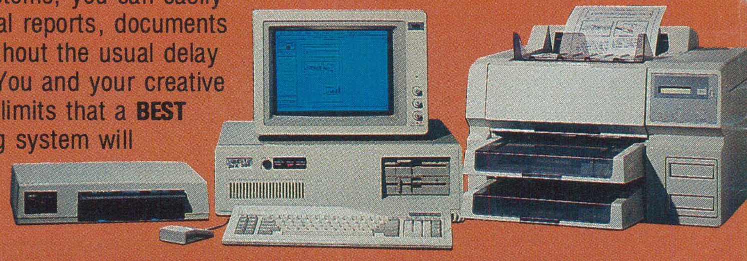

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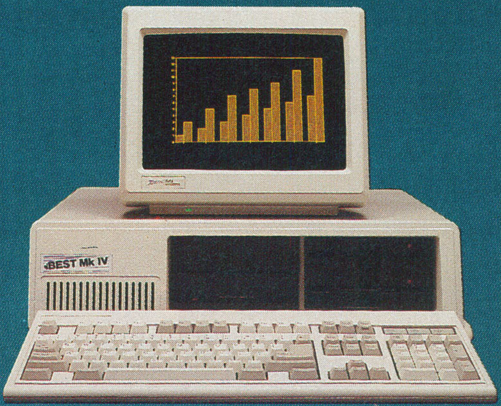


BEST MARK IV

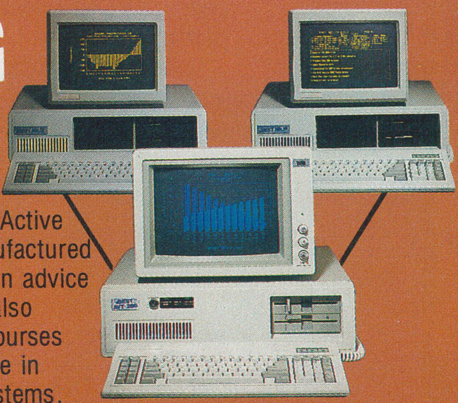
Basic System, Standard Features • IBM PC/XT Compatible • Based on 16 bit INTEL 8086-2 Microprocessor • Phoenix BIOS **Hardware Selectable Speed** • 8MHz or 4.77MHz **Disk Storage: two Floppy 5 1/4 inch diskette drives** • Drive A: 360 Kilobytes capacity • Drive B: 360 Kilobytes capacity **Memory Capacity** • 640 Kilobytes of RAM **Standard Peripheral Interfaces** • Two serial interfaces • Parallel Printer interface • Real Time Clock/Calendar with Battery Backup • Hardware Reset switch • 7 IBM PC/XT compatible expansion slots **Power Supply** • 130 watt total power, 90 to 132 VAC-50/60HZ, 198 to 264 VAC-50/60HZ • Switched and fused Auxiliary power connector.

BEST
AVT 10-286

BEST AVT 10-286

Basic System, Standard Features • IBM AT Compatible • Based on 16 bit INTEL 80286 Microprocessor • Phoenix BIOS **Hardware Selectable Speed** • 10/8MHz or 10/6MHz **Disk Storage: two Floppy 5 1/4 inch diskette drives** • Drive A: 1.2 Megabytes capacity • Drive B: 360 Kilobytes capacity **Memory Capacity** • 640 Kilobytes of RAM or • 2 Megabytes of RAM expandable to 4 Megabytes **Standard Peripheral Interfaces** • Two serial interfaces • Parallel Printer interface • AT Compatible Real Time Clock/Calendar with Battery Backup • Hardware Reset switch • 7 expansion slots: 2 IBM PC compatible expansion slots; 5 IBM AT compatible expansion slots **Power Supply** • 200 watt total power, 90 to 132 VAC-50/60HZ, 198 to 264 VAC-50/60HZ • Switched and fused Auxiliary power connector.

NETWORKING



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Toshiba has just given the portable laptop

a lot more bytes.

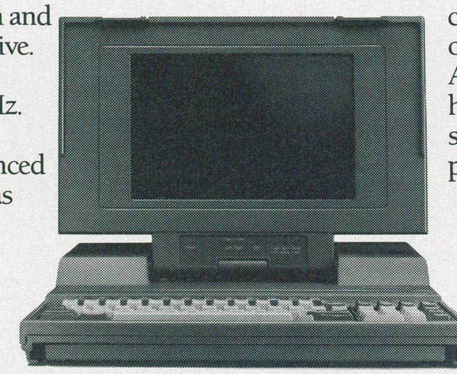
Introducing the exciting new Toshiba T3200. The portable laptop computer designed to take a big bite out of the desktop AT market.

While you're chewing over that data, consider some other major features of the T3200. It's a portable laptop that comes standard with one and one-half internal IBM*-compatible slots for hardware expansion and a fast 40-megabyte internal hard disk drive.

The T3200 moves fast too, with an 80286 microprocessor running at 12MHz. It's also very easy to read, with a superb Gas Plasma screen which is EGA (Enhanced Graphics Adapter) compatible. And it has even more bytes with the standard one megabyte of RAM, upgradable to four megabytes. There's also a separate numeric keypad within the full standard keyboard, for real ease of use. And with all this, there's the added advantage of true portability.

To learn more about the multi-purpose T3200, place a call to your authorized Toshiba re-seller, or call Toshiba direct at 1-800-387-5645. Ask for a demonstration. Once you've had a taste of the new T3200, you'll be spoiled for any other PC, desktop or portable.

The best keep getting better!



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Electronics &
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Canada's Magazine for High-tech Discovery
Volume 12, Number 2 February, 1988

The Amiga 500, page 18, and the Radio Shack Sound Level Meter, page 22, were photographed by Bill Markwick.

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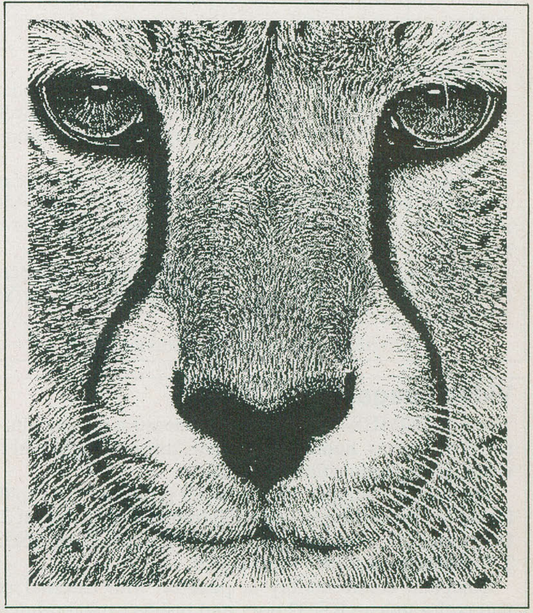

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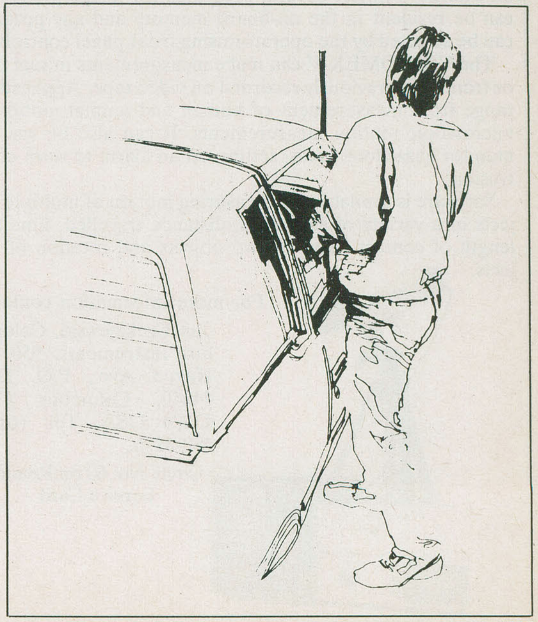

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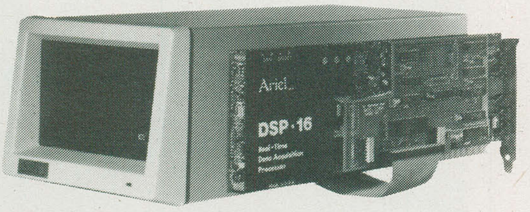
For Your Information



Real-Time Data Acquisition

The SDI (nothing to do with Star Wars) Signal-to-Disk Interface from Ariel Corporation allows host independent, real- time, full bandwidth data acquisition to disk, as well as signal editing and processing for any PC.

An Ariel DSP-16 Data Acquisition Processor combined with a high speed SCSI interface and the Ariel DSPDISK software, permits recording and playback on up to seven high capacity memory devices. SDI allows direct-to-disk recording/playback of 16-bit data at sample rates of up to 50 KHz on two channels simultaneously. The recorded signal can be viewed graphically and edited; parts of the signal can be marked, zoomed, moved, repeated, attenuated, deleted; special effects can be added; and the revised signal can be saved and played back.

The software is menu driven with all features controlled by either function keys, cursor, or mouse. DSPDOS allows users and third parties to develop programs for custom applications.

The system includes a DSP-16, an SCSI piggyback card, DSPDISK and DSPDOS, and a choice of a 50 or 250 Mbyte internal or external hard drive, or an 800 Mbyte WORM drive. Prices start at $3495 (US).

For more information contact: Elizabeth K. Vanderbilt, Ariel Corporation, 110 Greene Street, Suite 404, New York, NY 10012. Tel: (212) 925-4155.

Circle No. 59 on Reader Service Card

Video Image Analyzer

The VIDEOMEX-V is designed to measure movements (activity) of objects, humans or animals through rapid real time video picture acquisition and analysis.

The unit is equipped with a 68000 processor for rapid information processing as fast as 30 frames per second, at 256 x 192 resolution, from any standard PAL, NTSC, or SECAM TV camera or recorder video signal.

Complete connectability is possible with external computers through an RS232 port, and results can be printed on an external printer. Several programs for image processing can be resident in the on-board memory and any program can be selected by the operator using front panel controls.

The VIDEOMEX-V can make measurements in real time or from data previously recorded on video tape. Applications range from measurement of human and animal motion to microscopic motion measurements. It can also be used to monitor hazardous areas, setting off an alarm to warn of intrusion.

Software is available for measuring motion of multiple objects in a variety of situations, distance travelled, time and length of contact between two objects and rotation of objects.

For more information contact:

Jan Czekajewski, Columbus Instruments, 950 N. Hague Ave., P.O. Box 44049, Columbus OH 43024 USA. Tel: (614) 488-6176.

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Happenings

Event: Software/Logiciel Symposium 88
Date: February 3–4, 1988
Location: Metro Convention Centre, Toronto
Contact: William Hutchinson & Co. (416) 498-5344

Event: International Conference on Computers and Law
Date: February 8–10, 1988
Location: Miramar Sheraton Hotel, Santa Monica, CA USA
Contact: Michael Krieger (213) 208-2461

Event: The Business Computer Show
Date: March 2–4, 1988
Location: Automotive Building, CNE, Toronto
Contact: Marion Hart (416) 252-7791

Event: Facsimile & Image Communications Conference
Date: April 11–13, 1988
Location: Marriot Copley Place, Boston Mass.
Contact: Martha Johnson (617) 837-1341

Event: Canadian High Tech Show
Location: Lansdowne Park, Ottawa
Date: May 3–4, 1988
Contact: CHTS (613) 731-9850

Event: CIPS' Congress '88 (Can. Info. Processing Society)
Date: May 18–20, 1988
Location: Metro Convention Centre, Toronto
Contact: CIPS (416) 593-4040

Event: EEMAC Annual Conference
Location: Lowes Concorde Hotel, Quebec City
Date: June 8–10, 1988
Contact: EEMAC (416) 674-7410

The Standards Approval Group Inc. would like to announce the opening of their new corporate headquarters located at 175 Traders Boulevard East, Mississauga, Ontario. Along with their recently launched EMI test facility in the Caledon Hills, north of Toronto, Standards Approval Group offers one-stop testing and certification for computer and communications-related products.

Last month we published an incorrect phone number for the Standards Approval Group, the correct phone number is 890-2800. Our apologies to anyone who may have been inconvenienced by this error.

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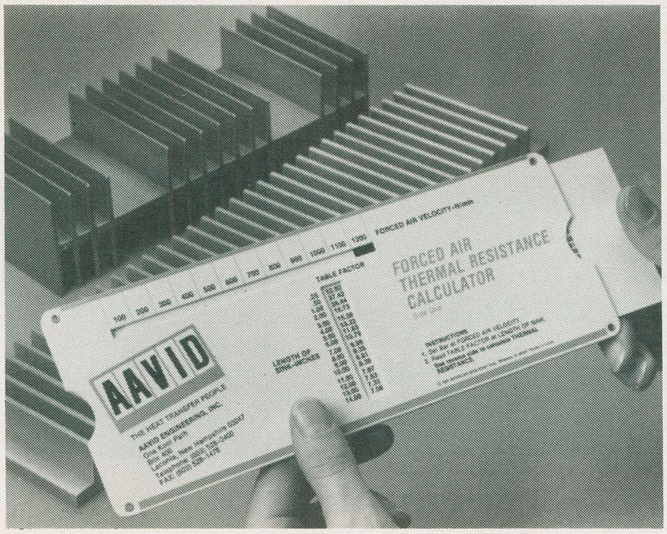

Free Slide Chart

A new slide chart for determining the thermal resistance of extruded heat sinks is available, free, from Aavid Engineering, Inc. Engineers will find this particularly useful for calculating thermal performance more easily, quickly, and accurately.

The Forced-Air Thermal Resistance Calculator can be used to determine any of the following parameters: air flow velocity; thermal resistance; heat sink length; or heat sink cross section.

In addition, the slide chart includes conversion ratios for calculating natural convection thermal resistance for heat sink extrusions from 1 inch to 15 inches long.

For more information contact: Future Electronics, 237 Hymus Blvd., Pointe Claire, Quebec, H9R 5C7.

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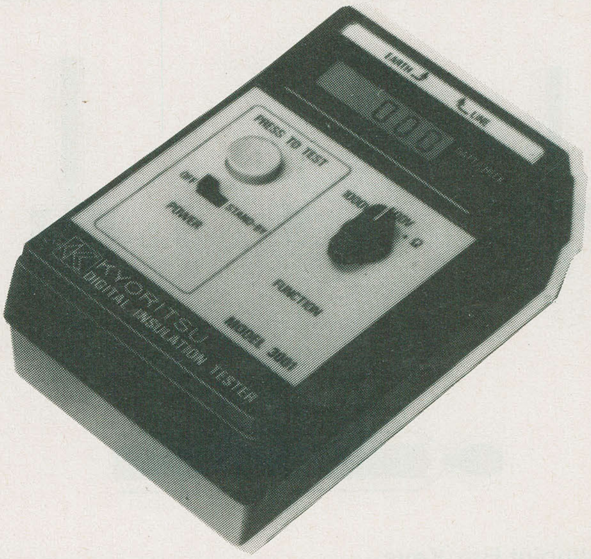

Digital Insulation Resistance Tester

The Model 3001 from Kyoritsu is a compact, light weight, 3 1/2 digit insulation resistance tester with test voltages of 500V and 1000V at 200 Mohms. The unit has autoranging (2/20/200Mohm) and continuity up to 200 ohms.

Other features include: live circuit warning, automatic discharge of circuit capacitance when Test button is released, overload protection and LED battery check.

The 3001 comes complete with test leads, case, and a two year parts and labor warranty.

For more information contact: Omnitronix Ltd., 2410 Dunwin Drive #4, Mississauga, Ontario L5L 1J9. Telex 06-22324

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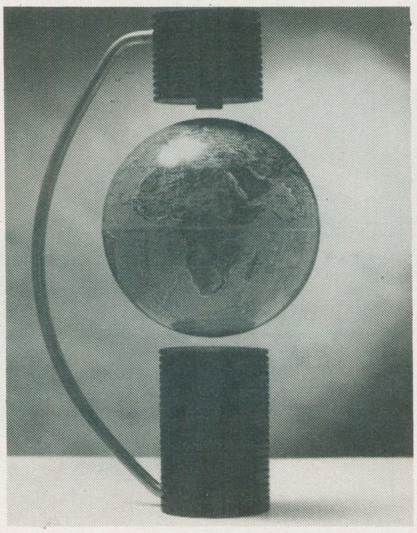

Magnetic Levitation Globe

Black magic? Mirrors? Slight of hand? Nope, it's the world magnetically levitated right before your eyes, and it's brought to you by Maglev Sales of Vancouver B.C.

The six inch maglev globe is based on the same operating principle as the levitated train currently being tested by Japan Airlines. The method used is to electronically sense the position of the globe and regulate the power of the magnets which lift it.

Great for the science class or as a novelty for the desk, the globe is available from Maglev Sales at a cost of $189 (US). You can reach them at: 1030 West Georgia Street - Suite 31, Vancouver, B.C. V6E 2Y3. Tel: (604) 682-5824.

Circle No. 52 on Reader Service Card

Hioki LCR Tester

The 3520 LCR tester from Hioki will aid in improving reliability of electronic parts and materials such as capacitors, coils, resistors and insulators by evaluating them under almost-actual conditions.

The unit features a range of frequencies from 40 Hz to 100 KHz, selectable signal levels in 11 steps up to 1 VACRMS, and two selectable test modes (serial equivalent and parallel equivalent).

In addition, the unit is equipped with a GPIB interface for connection to automatic measurement equipment offering greater precision in selecting frequency and signal levels. Other features include: residual charge protection circuit for capacitors; 4-terminal measurement system; DC biasing; and a function lock to guard against incorrect readings due to accidental setting changes.

For more information on the 3520 contact: RCC Electronics, 310 Judson Street, Unit 19 ,Toronto, Ontario M8Z 5T6. Tel: (416) 252-5094 Fax: (416) 252-3031

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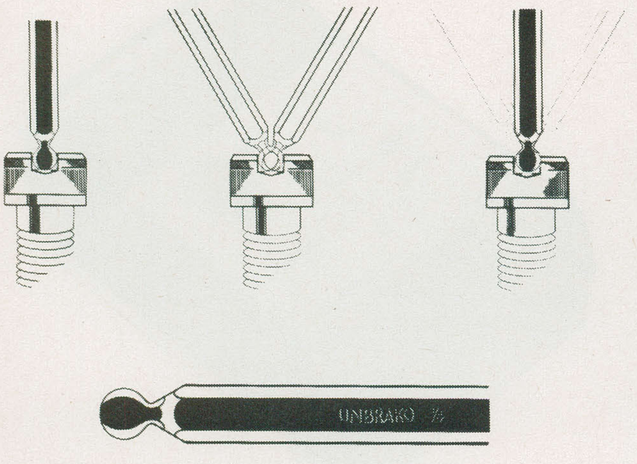
For Your Information

Continued on page 14



Ballpoint Hex Keys

Unbrako offers a full line of ballpoint hex keys in sizes from .050" to 3/8" that permit angled entry and full socket engagement. Socket screws can be tightened at angles up to 30 degrees, allowing access to sockets located in extremely confined areas. Alignment of socket and wrench is facilitated by the ballpoint tip, even in areas of limited visibility.

The keys are available in two configurations: screwdriver-type with handles proportioned to allow the user to reach maximum recommended ballpoint hex key torque, and in an L- wrench shape that offers two tools in one, with the ballpoint for off-axis driving and the long arm which furnishes the leverage for full torque.

Contact: Larry Simpson, Standco Canada Ltd., 101 Spinnaker Way, Concord, Ontario L4K 2T2. Tel: (416) 738-4050.

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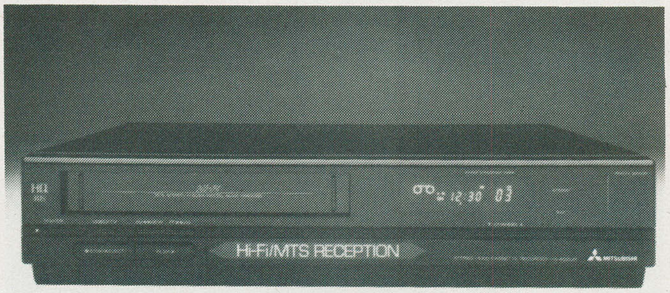

Hi-Fi VCR

The Mitsubishi HS-402UR features HQ circuitry, 25- function infrared remote with direct channel access, VHS Hi-Fi with stereo MTS/SAP reception, 107 channel tuner, and 5-event/2 week programmability.

Other features include auto-rewind, auto-on play, auto record protection, and power off eject. Available from authorized Mitsubishi dealers across Canada.

Contact: Product Manager, Mitsubishi Electric Sales Canada Inc., 8885 Woodbine Avenue, Markham, Ontario L3R 5G1. Tel: (416) 475-7728.

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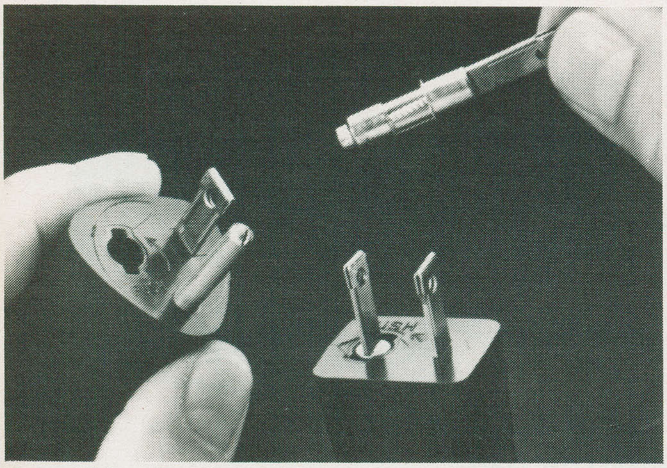

Fused Line Cord

Belden's new Fused Line Cord is available in two and three-conductor sizes, and features a field-replaceable fuse as part of the male termination.

Ideal in a broad range of applications where shorts and overloads are a concern, such as in personal computers, home appliances and tools, the FLC is available in a range of fuse ratings from 1/4 to 6 amps depending on the application.

The Fused Line Cord also provides circuit selectivity. Previously, a fault would cause a loss of power to the entire circuit, but with FLC the fault is isolated leaving the rest of the circuit to operate normally.

The field-replaceable Buss fuse is integrally mounted into the male end of the line cord. It is simple to replace; no tools are required.

Available from Canadian Belden distributors or for more information contact: Belden Division of Cooper Industries, 2000 South Batavia Ave., Geneva, Illinois 60134. Tel: (312) 232-8900.

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Celtron-1
POWER
ON
DETECT

Service Technicians Take Note!

CELTRON-1 is a feature-packed remote infrared and ultrasonic transmitter tester. It tests transmitters quickly and easily, and displays test results by both a green LED and audible 'beep'. CELTRON fits neatly into your shirt pocket (with all those other pocket size instruments) ensuring that it will always be handy. AUTO-OFF allows for longer battery life, while a handy scope/frequency counter test jack allows for the utmost in accurate testing.

Ideal for testing TVs and TV converters, satellite receivers, VCRs, CDs, stereos, alarm systems... the list is endless. The price is right too! But you'll have to contact CableServ Electronics Ltd., 18 Dufflaw Road, Toronto, Ontario M6A 1C8 to get the bottom line. Or phone 'em at (416) 789-4581. Or...

Circle No. 65 on Reader Service Card

Electronic Image Processing

A look at how far image processing has progressed.

By Dr. H. Virani

Electronic image processing is now about two decades old. The field has experienced accelerated international interest in this relatively short time and already the volume of original research work has reached staggering proportions. This is not surprising for two major reasons.

First, the use of computers is central to the processing of picture information in digital form and the cost/performance improvements in computing hardware have been sustained at very high levels throughout this period. This has encouraged the expansion of image processing methods based upon the computer realization of mathematical models of a wide range of imaging problems expressible fundamentally from the spatial distribution of intensity data, usually in two dimensions and frequently restricted to monochrome images. The rapidly increasing computational capability and low cost RAM for modern computers has permitted research experiments within manageable time frames and at acceptable cost.

The second major impetus in the field has been the immediate recognition of the outstanding potential for the use of imaging in an extensive range of commercial and industrial applications. This too has been reflected in the number of application orientated papers in the literature and the dedication of some conferences to this particular aspect.

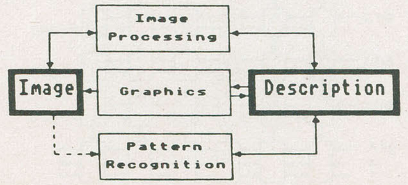


Fig.1 The interaction of the three major components of the image processing system.

Technical context

The term "image processing" is now widely used but is frequently employed to include the more general processing problems associated with computer graphics and pattern recognition.

Fig. 1 gives the conceptual interaction between these three important areas and expresses the general flow of information in terms of actual data but also in relation to fundamental conceptual idea movement. Strictly speaking each of the areas represents distinct discipline and each has its dedicated protagonists. As far as image processing in its wide sense is concerned, however, it is likely that the most exciting developments will emerge from the exploitation of the interaction summarized in Fig. 1.

Fig. 2 gives a simplified view of the general development phases of image processing as a discipline and indicates the growing awareness of the potential for the application of early theoretical work in the subject.

1	Image capture	Vidicon Digitisers CCD Line scan
2	Image description	1965
3	Linear processing	o n
4	Enhancement Restoration	w a
5	Analysis	r d
6	Coding	s
7	Database engineering	1984 -
8	Real-time imaging	1984 -
9	VLSI image engineering	1985 -

Fig. 2 A simplified view of the general development phases of image processing.

This is particularly apparent from the growth of applications utilizing high performance real-time processing both in conventional computing or microprocessor terms or, more recently, in terms of direct silicon based processing as exemplified by array and generalized VLSI systems.

Fig. 1. represents a simplified view of image processing but illustrates the important principle that many applications will only be realized by a combination of two or even three of the related areas. This fact poses some of the most exciting challenges for the engineer in the generation of viable products.

The Information Engineering Challenge

Fig. 1 expressed the potentially complex interaction between image processing, computer graphics and pattern recognition. In simple terms, image processing accepts an image and converts it to some other via transformation in a mathematically descriptive domain. Since most real-world scenes are two-dimensional this involves a considerable capability in matrix and linear transformation theory but in itself is a straight forward mathematical process lending itself to computer execution.

The modern information engineer will normally be adequately equipped educationally to meet this challenge. However, the realization of image processing algorithms for specific practical applications necessitates the employment of pattern recognition methods. Fig. 3 provides a generalized summary of the inherent functions of pattern recognition systems.

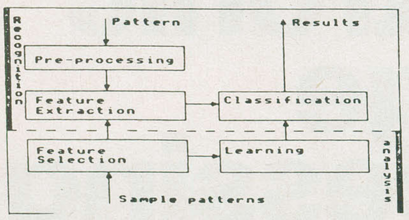


Fig. 3 A generalized summary of the inherent functions of pattern processing

In this approach the primary concern is the classification of patterns through comparisons between the input and samples. The diagram shows the interaction between the activities involved and the flow of data between them. It is clear however, that although the mechanism of operation of the activities must be modelled mathematically and executed in the computer system the underlying principles reach far beyond the rigorous modelling processes. The learning module will be heavily driven by a prior knowledge of the input scene and about the nature of the desired results. This implies that the complete system will require computer modelling of many human perception phenomena.

This particular facet promises to be one of the most challenging components in the successful development of new image processing based systems.

Computational Speed

However this does not imply that all successful hardware systems must attempt to emulate the human visual and perceptive mechanisms although there is much active research in this area.

The most significant impediment to the exploitation of human visual and perceptive mechanisms in hardware is the present inadequacy of performance and speed for available processing equipment. This problem is aggravated by two important factors.

First application dedicated computers are now of the microprocessor type and although impressive computing performance can be achieved with clock rates up to 20 MHZ the hardware architecture is bus bound. This places severe limitation on the possible processing throughput of a particular machine.

Second, many of the more promising applications such as industrial inspection or measurement dictate an image resolution at least up to 512 x 512 pixels giving 265 Kb grey scale data. Linear manipulation of this volume of data is highly memory dependent with consequent degradation of throughput speed. Much of the present research effort is therefore directed towards reducing the volume of image data required and this necessitates sophisticated coding techniques combined with advanced data structure and analytical methods.

An example is the quadcode approach which seeks to code an image by repeated division of the scene into quadrants and coding grey levels in each. The theory of quadtrees and its application is showing considerable promise in the successful reduction in the total bit count required to specify completely an image in a manner which is reversible without significant loss of accuracy.

Gate Array Technology

The requirement for increased computational speed persists despite data volume reduction and this has given accelerated impetus to the search for advanced processing systems.

An excellent example of this is the use of gate array technology to implement rudimentary image processing and pattern recognition algorithms.

Fig. 4 gives a summary of the performance capabilities for a particular family of gate arrays. These arrays are moderately fast with typical switching delays of about 2-6 ns for a 4-input NAND fate cell with a fanout of 4. This technology has the major advantage of being relatively inexpensive for the end user since the basic array elements and the first level of integration into operating cell is prefabricated in the manufacturing domain and only the application specific macro selection and interconnection need be carried out at customer level.

ARRAY	FGC0500	FGC2400	FGC4000	FGC6000
Gates	540	2592	4020	6000
Usable gates	432	2073	3216	4800
Inputs	0	39	47	55
I/O	40	70	86	106
Total I/O	40	109	133	161
Power pins	4	8	8	8
Test pins	0	3	3	3

Fig. 4 A performance summary for a particular family of gate arrays

Large turnkey image processing systems already include array processors which can achieve near real-time performance. However the realization of these systems in the price range appropriate for many applications is still largely uneconomical and this particular challenge remains for the engineer and information engineer to solve.

Systolic Arrays and VLSI

A more recent innovation in high speed processing is the systolic array. A typical array structure is indicated in Fig. 5.

The simplicity and repeatability of the inherently simple structure makes the device an ideal candidate for implementation directly on semiconductor VLSI technology. The regular lattice layout minimizes interconnection distances and hence the operating speed approaches the maximum possible with current semiconductor technology.

The systolic processing mechanism makes the device the natural choice for a wide range of Fourier and Laplace operations which are central to many image processing operations. The automatic pipelining of data flow implies that the complete chip area can be contributing to the accumulation of valuable results at all times and with fundamental clock rates of 25-35 MHZ for 2 micron CMOS technology, this

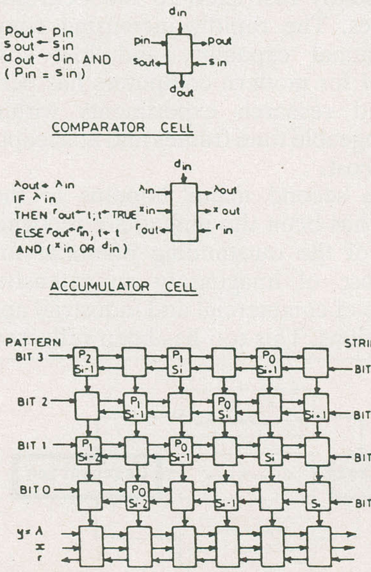


Fig. 5 Representation of a typical array structure.

A Question of Balance

A fresh look at a frequently misunderstood topic — the use of balanced lines for audio signal connections.

By Barry Porter

It's well known that something called balancing is important in the world of professional audio, but not many people seem to know what the system does or what advantages it brings. If you fall into this category and would like to know a little more, read on.

The individual units of a domestic system, such as a preamplifier and a power amplifier, are usually connected together with a length of screened cable (Fig. 1). Signal is carried along the inner conductor, and the outer screen joins the ground lines of the electronics in the two items of equipment. This type of interconnection is termed 'unbalanced' and works well enough providing the cable is not of excessive length and does not pass near to a strong source of electrical interference. Although the screen layer gives some protection to the signal carrying conductor, a strong external AC field such as that surrounding an AC transformer will pass through the screen and add its unwanted modulation to the signal.

This problem is obviously at its greatest when the cable carries signals at a low level and is followed by lots of amplification. An example is the connection between a microphone and the input channel of a mixing console, where any hum and noise picked up by the cable may be amplified by as much as 60dB.

One way to minimize the effect of external hum and noise is to keep the line impedance as low as possible and the signal level as high as possible. If the sending amplifier has a very low output impedance — less than 1 ohm is possible with operational amplifiers — the connecting cable appears to be at about ground potential, and external fields will exert very little influence.

This principle works well for cable runs of less than 30 metres or so where the external field is not too intense, but when long interconnections are used, the resistance of the signal carrying wire becomes significant and the line impedance increases as you get further from the sending amplifier. In some cases, it is not possible to achieve a near-zero source impedance.

A typical moving coil microphone has an impedance of 200 ohms, and some equipment which has passive attenuation or equalization after the final stage may have an output impedance of several kilohms — ideal circumstances for the introduction of noise whenever connected to a few metres of cable.

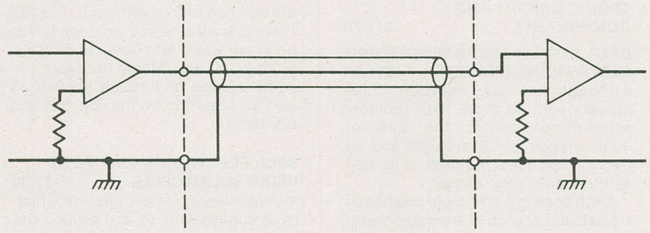


Fig. 1 An unbalanced signal connection, as used on most domestic audio equipment.

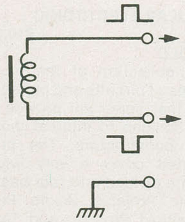


Fig. 2 A balanced output as provided by a moving coil microphone or a transformer.

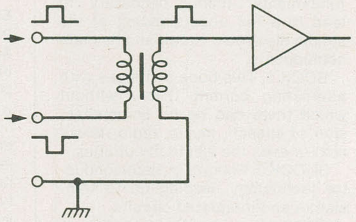


Fig. 3 A differential (or balanced) input using a transformer.

Yet microphones in particular are often required to be at the far end of several hundred meters of conductor, along which a signal with a level of 1mV or less must travel with as little corruption as possible. Can any thing be done to minimize the pick-up of hum, noise and RF that doesn't require considerable lengths of metal conduit piping? Luckily, it can, and it's called balancing.

The easiest way to understand how balanced connections work is to consider a moving coil microphone. It will consist of a thin foil diaphragm to which is attached a lightweight coil, suspended in a powerful magnetic field. The diaphragm and the coil are vibrated by incoming sound waves, and this vibration is turned into an electrical current by the action of the magnet. The ends of the coil are connected to the microphone output socket (Fig. 2) where the output signal voltage appears with a phase difference of 180 degrees between the two contacts.

Let's turn to a type of input circuit usually referred to as differential and typified by the transformer arrangement shown in Fig. 3. In order to produce an output voltage, the transformer inputs must receive two signals which are identical in every way except that they must exhibit a 180 degree phase difference — just what the microphone gives out.

If the two outputs of the microphone are now connected to the two transformer inputs, a balanced circuit is created. In practice, the two conductors are enclosed by a screen layer which in the example given would connect the metal case of the microphone to the input amplifier ground. This is shown in Fig. 4 along with the amplification stage which follows the input transformer.

You may wonder what is so different between that and an unbalanced connection. Luckily, there is a big difference. If the cable connecting a balanced output to a balanced input picks up any hum and noise, the unwanted voltages will occur in both conductors at the same level and most importantly, with the same phase. Since a balanced circuit requires a 180 degree phase difference between its two inputs, any signals arriving which are not in anti-phase are cancelled by the differential action of the input. This removes the hum and noise.

The ability of a balanced input to reject unwanted signals is called the Common Mode Rejection Ratio (CMRR for short), and is measured as shown in Fig. 5. CMRR values tend to be frequency conscious, rejection becoming progressively worse with increasing frequency. By careful design, particularly with solid state inputs, a rejection of 80 or 90dB across the audio band may be achieved.

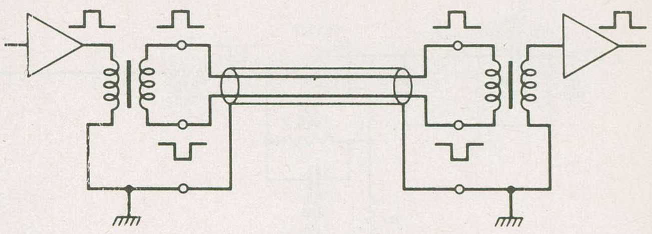
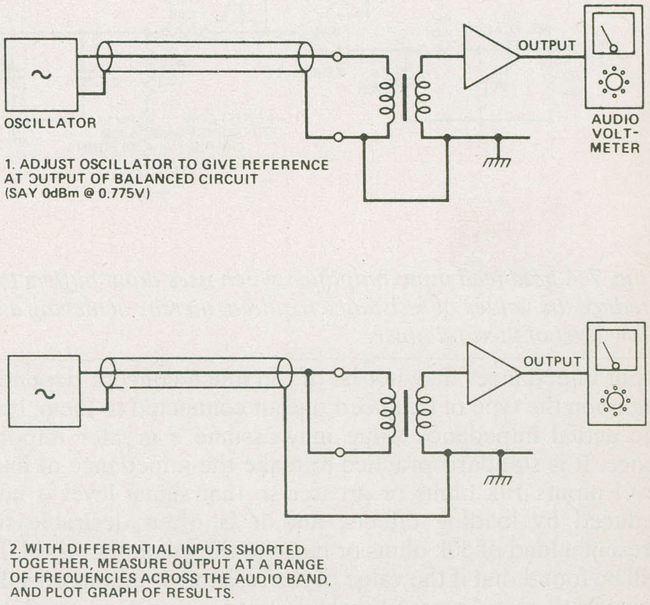


Fig. 4 A balanced interconnection between two pieces of equipment.



1. ADJUST OSCILLATOR TO GIVE REFERENCE AT OUTPUT OF BALANCED CIRCUIT (SAY 0dBm @ 0.775V)

2. WITH DIFFERENTIAL INPUTS SHORTED TOGETHER, MEASURE OUTPUT AT A RANGE OF FREQUENCIES ACROSS THE AUDIO BAND, AND PLOT GRAPH OF RESULTS.

Fig. 5 Measuring the Common Mode Rejection Ratio (CMRR) of a differential input.

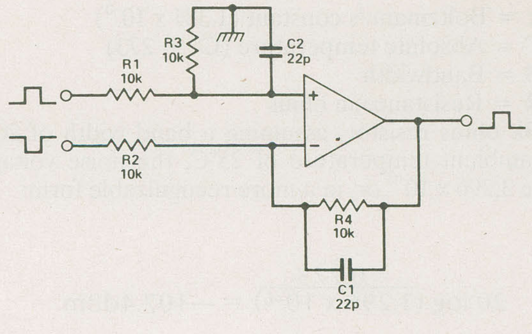


Fig. 6 Balanced input circuit using a single op-amp.

Transformer Or Solid State?

Until recent years, the standard balanced circuit invariably employed transformers for both input and output coupling. By using transformers the signal can be madè to pass from the output of one piece of equipment to the input of another without an ground reference, so removing the risk of hum loops. This is particularly important in radio and TV studios, so transformer balancing is almost universal in these environments.

Transformers do suffer from a number of shortcomings. Without becoming too large for comfort, they will only pass a limited signal level before introducing large amounts of very nasty distortion, particularly at low frequencies. They can also suffer from undesirable phase shifts unless carefully designed. High quality transformers are also rather expensive — 'Professional Grade' versions can cost as much as $50-$100.

Although balancing (and unbalancing) transformers are still used in large quantities, for many applications they are being rapidly replaced with solid state input and output stages. A standard operational amplifier has a differential input, and can be connected to a balanced line, as shown in Fig. 6. To obtain the best common mode rejection, the four resistors must all be of the same value, and it is usual to use a variable and fixed resistor in series for R3 to allow the CMRR to be trimmed at low frequencies. The two capacitors also need to have the same value, and C2 is often small trimmer in parallel with a fixed component that is lower in value than C1. With careful adjustment, the CMRR can be as high in value as 90dB across the audio band. This circuit can give excellent results, but has a few shortcomings which rule out its use in high quality equipment.

The two inputs have differing impedances because R2 is terminated by a virtual ground whereas R1 is loaded by R3 in parallel with the input impedance of the op-amp. Unequal

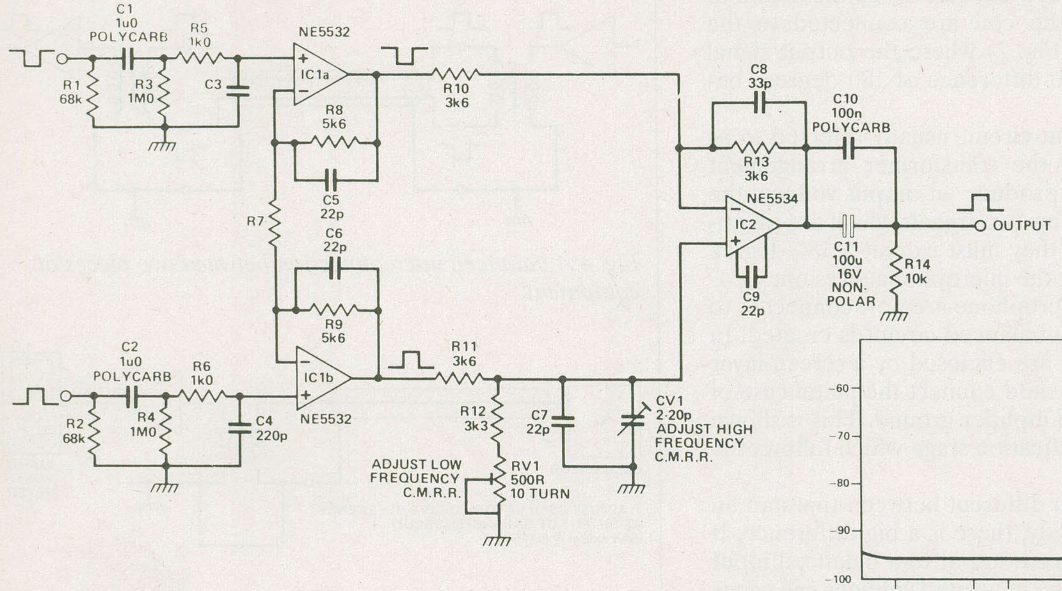


Fig. 7 A balanced input amplifier which uses input buffers to reduce the values of resistance required, thereby achieving a low level of thermal noise.

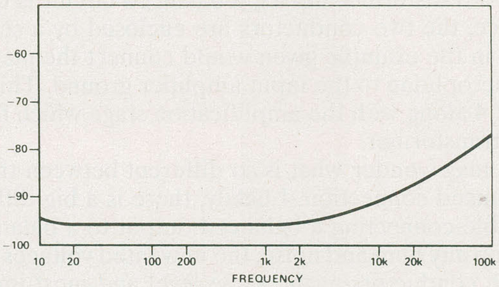


Fig. 8 The common mode rejection offered by the circuit of Fig. 7.

input impedances may not be of too much concern depending upon the type of balanced output connected to them, but the actual impedance value may assume a greater importance. It is standard practice to make the impedance of line level inputs 10k ohms or greater so that signal level is not reduced by loading effects, and it is often desirable to present a load of 50k ohms or more to the incoming signal. It will be found that if the value of the resistors is increased sufficiently to give a reasonably high input impedance, say 33k, then thermal noise has to be considered.

The noise voltage of a resistor is given by:

$$\sqrt{4kTBR}$$

Where k = Boltzmann's constant (1.381×10^{-6})
T = Absolute temperature (C° + 273)
B = Bandwidth
R = Resistance in ohms

For a 33k ohms resistor, assuming a band width of 20kHz and an ambient temperature of 25°C, the noise voltage is therefore 3.296×10^{-6} or, in a more recognizable form:

$$20 \log \left(\frac{0.775}{3.296 \times 10^{-6}}\right) = -107.4\text{dBm}$$

which is not particularly brilliant. Now, if the resistor value is reduced by a factor of 10, its noise contribution will be reduced by 10dB, which is a significant improvement.

A practical circuit which takes account of thermal noise problem is shown in Fig. 7. It is essentially the same as the circuit shown in Fig. 6 except that buffers have been added to each of the inputs. These allow the impedance of each input to be the same and of virtually any value required, yet the resistances around the differential stage may be low enough to avoid noise problems. An additional advantage is that the stage gain can be adjusted by changing one resistor — R7. The gain is calculated from:

$$20 \log \left(\left(\frac{R8 + R9}{R7} \right) + 1 \right)$$

or for a required gain,

$$R7 = \frac{R8 + R9}{A \log \left(\frac{Av(dB)}{20} \right) - 1}$$

This stage is ideal for the line level inputs operating over a gain range from unity to 20 or 30dB. It has low noise, negligible distortion (typically 0.002% over the audio band) and excellent common mode rejection (see Fig. 8). To adjust RV1 and CV1, use the set-up shown in Fig. 5. With a 100Hz input signal, set RV1 so that the circuit output voltage is at its minimum level, then reset the oscillator to 15kHz and trim CV1 for minimum output.

This circuit is often referred to as an 'Instrumentation' input. As well as being an ideal balanced input stage for pre and power amplifiers, mixing consoles etc, it also makes a suitable input for many types of high quality test equipment. Audio frequency voltmeters, distortion meters and many other instruments use the circuit because it has very stable and clearly defined gain characteristics and a wide bandwidth with an extremely flat frequency response. With the component values shown in Fig. 7, the -3dB points are at approximately 0.5Hz and 150kHz with less than 2° of phase lead at 20Hz and about 7° of lag at 20kHz.

A number of changes may be introduced to optimize the circuit for specific applications. Input noise may be reduced by replacing C1 and C2 with 10u or 22u non-polarized electrolytics (not forgetting to put a 100n polycarbonate in parallel with each one in the interest of sound quality!) This will also give a few more dB of common mode rejection at low frequencies, and the phase shift at 20Hz will be reduced to 0.06. For use in test equipment, C3 and C4 should be reduced to 47p in order to keep the response flat to 100kHz.

Stage gain may be made adjustable by using a single pole switch to select different values of R7 or a potentiometer in series with a fixed resistor (see Fig. 9). Note that AC coupling has been introduced to avoid problems from switch clicks or potentiometer wiper noise which would otherwise arise due to inevitable DC offsets at the op-amp inputs.

If an accurate stepped attenuator is placed in front of this circuit and some additional gain stages added after it, you have the input stage of a professional-quality audio voltmeter which will give FSD readings from 300V to 10uV – a range of 150dB! (When some further development work has been carried out, you may have the pleasure of constructional article based on it).

So far, we have looked at the balancing of high level signals, but there are far more benefits to be gained by employing the same techniques when signal levels are in the milli or microvolt region. For a high quality microphone amplifier, the basic configuration of Fig. 7 may be used but with a few important changes.

The biggest single problem with microphone amplifiers is keeping the noise contributed by the active stage as low as possible. The thermal noise of a 200 ohm source is 129.6dBm, so a perfectly silent microphone amplifier with a gain of 60dB and a 200 ohm input load, would have an output voltage of -69.6dBm over a 20kHz bandwidth. If a real amplifier has an output of -67dBm, it is said to have a noise figure of 2.6dB. Some manufacturers claim noise figures as low as 1dB, but 1.5dB is a more realistic aim, and the circuit of Fig. 10 can achieve this providing great care is taken with construction and component choice.

The input impedance is fixed at 1k2 ohms by R4, this being the currently accepted value for loading 200 ohm

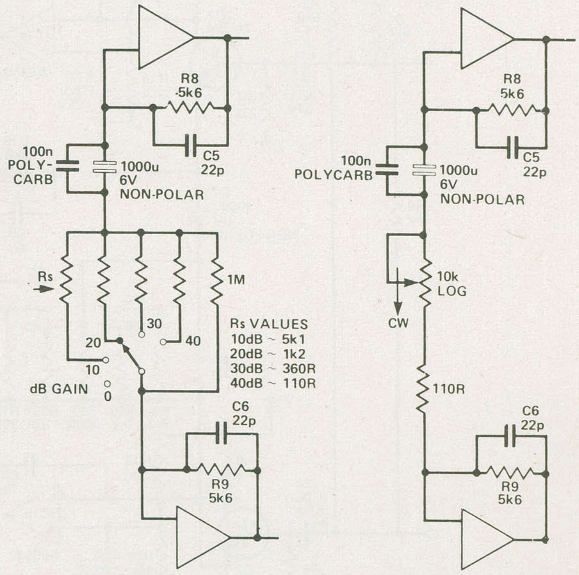


Fig. 9 The circuit of Fig. 7 can be modified to provide either (a) switched gain or (b) continuously variable gain.

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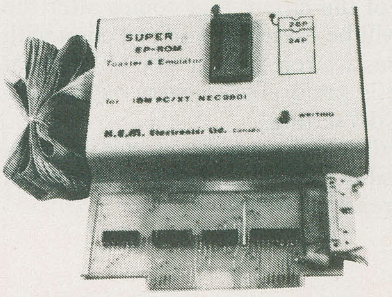

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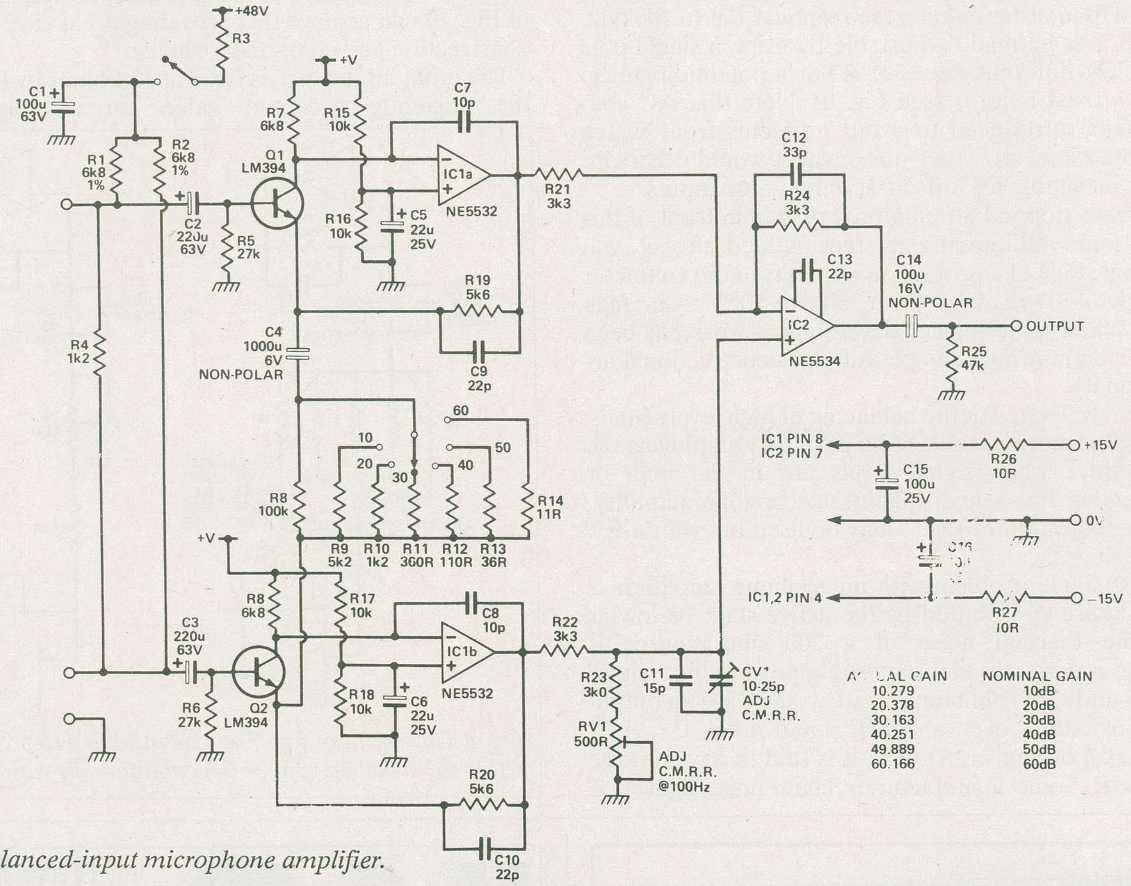

+48V
R3
C1 100u 63V
R1 6k8 1%
R2 6k8 1%
C2 22u 63V
R5 27k
Q1 LM394
+V
R7 6k8
R15 10k
C7 10p
IC1a
NE5532
R16 10k
C5 22u 25V
R19 5k6
C4 1000u 6V NON-POLAR
C9 22p
R4 1k2
R21 3k3
C12 33p
R24 3k3
C13 22p
C14 100u 16V NON-POLAR
IC2
NE5534
OUTPUT
R25 47k
10
20
30
40
50
60
R8 100k
R14 11R
R9 5k2
R10 1k2
R11 360R
R12 110R
R13 36R
IC1 PIN 8
IC2 PIN 7
C15 100u 25V
R26 10R
+15V
0V
C16
IC1,2 PIN 4
R27 10R
-15V
+V
R8 6k8
R17 10k
C8 10p
IC1b
NE5532
C3 220u 63V
Q2 LM394
R6 27k
R18 10k
C6 22u 25V
R22 3k3
R23 3k0
C11 15p
CV1 10-25p ADJ C.M.R.R.
RV1 500R
ADJ C.M.R.R. @100Hz
R20 5k6
C10 22p

ACTUAL GAIN	NOMINAL GAIN
10.279	10dB
20.378	20dB
30.163	30dB
40.251	40dB
49.889	50dB
60.166	60dB

Fig. 10 A balanced-input microphone amplifier.

microphones. It may be changed if a different value is recommended by the microphone manufacturer. R1 and R2 apply 48V phantom power to energize capacitor microphones and should be closely matched, either by purchasing 1% tolerance components or by measuring with an accurate bridge of a digital multimeter. If the circuit is only to be used with dynamic microphones, R1, R2 and R3 together with C1 may be omitted, as may C2 and C3. This will give a slight improvement in signal-to-noise ratio and an improvement in sound quality due to the loss of a pair of electrolytic capacitors from the signal path. As the common mode rejection is adjusted at a part of the circuit that comes after the gain setting stage, there will be a variation of rejection with gain. Although more impressive rejection can be obtained at 10dB gain than at 60dB it is preferable to carry out the adjustment at the 30dB or 40dB setting.

With a carefully designed PCB layout, this circuit will perform as well as and possibly better than any professional microphone amplifier currently available.

Balanced Disc Stage

Another type of input stage that benefits from balancing is the RIAA pick-up amplifier, particularly when a low output moving coil cartridge is in use. Fig. 11 shows the disc input of a particular unit, which has a balanced input. Using such an arrangement may mean that minor surgery has to be carried out on the wiring of your pick-up arm in order to remove the ground connections from the signal leads, but the results will be found to justify this annoyance. Try it and see.

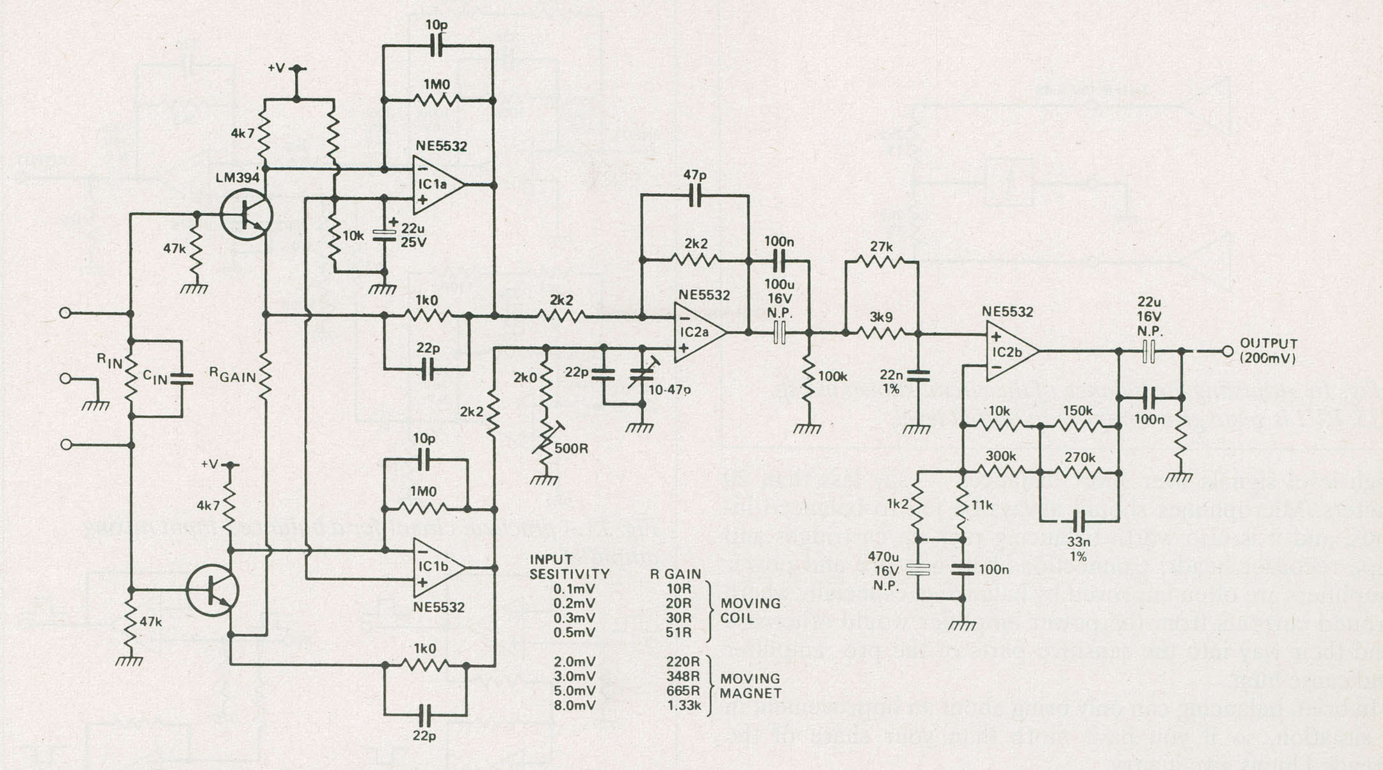
Balanced Mixing

The final balanced input circuit I have shown is that of a virtual ground mixing amplifier. Mixing busses are extremely sensitive to hum and noise, but the problem can be greatly reduced by adopting a balanced mixing system. Two basic arrangements are possible, the input channel amplifiers having either single-ended outputs or balanced outputs (Fig. 12). In both cases the signals feed into a differential input, and any noise voltages picked up along the bus lines will appear at the mixing amplifier inputs with the same phase and will be cancelled in the usual way.

A practical circuit for a differential input mixing amplifier is shown in Fig. 13. It resembles the line input circuit of Fig. 7, except that here the incoming signals are taken to the inverting inputs of the op-amps. The use of 3k3 resistors for feedback and mixing helps keep the noise down and the linearity is improved by having the input capacitors inside the feedback loop. With 3k3 input resistors, this circuit will accept up to fifty inputs with no low frequency problems and will attenuate common mode noise from mixing busses ten or twelve feet long by 60-80db

Balanced Outputs

Microphones and pick-up cartridges are intrinsically balanced, but amplifier outputs are not. The easy way out is to hang a transformer onto the end of a single-ended output stage, but in this day and age it is rumored that miraculous things can be done with a handful of chips and a bit of ingenuity.


10p
1M0
+V
4k7
NE5532
IC1a
LM394
47k
10k
22u 25V
1k0
22p
2k2
R_{IN}
C_{IN}
R_{GAIN}
2k0
22p
10-47p
500R
2k2
47p
2k2
100n
100u 16V N.P.
NE5532
IC2a
100k
27k
3k9
22n 1%
NE5532
IC2b
22u 16V N.P.
OUTPUT (200mV)
10k
150k
100n
300k
270k
1k2
11k
33n 1%
470u 16V N.P.
100n
+V
4k7
10p
1M0
IC1b
NE5532
47k
1k0
22p

INPUT SENSITIVITY	R GAIN	
0.1mV	10R	MOVING COIL
0.2mV	20R	
0.3mV	30R	
0.5mV	51R	
2.0mV	220R	MOVING MAGNET
3.0mV	348R	
5.0mV	665R	
8.0mV	1.33k	

Fig. 11 A balanced-input disc stage, providing RIAA equalization and suitable for use with moving coil cartridges.

If a balanced output is just two outputs in phase opposition, there are several ways of obtaining this (see Fig. 14). They all have on failing — namely that if one output is shorted to ground, the output level drops by 6dB because the peak-to-peak voltage swing is halved.

A solution is shown in Fig. 15, a balanced output stage which delivers the same level into balanced and unbalanced inputs. When this is used with an unbalanced input, it is essential that the unused output is shorted to ground as distortion and noise will otherwise increase.

The operation of this circuit is fairly obvious. Disregarding the input buffer, assume a 1V input at A which feeds both the inverting and non-inverting op-amps. Taking the inverting stage first (IC2a), you may expect there to be -1V at point B. Instead the cross-coupled feedback through R10 is attenuated by the potential divider R10, R7 and puts +0.25V onto the non-inverting input of IC2a. This is then amplified by 2 (think of R5 as a feedback shunt resistor connected to 0V) so the output becomes -1+(0.25x2) = -0.5V. The non-inverting amplifier (IC2b) has a gain of 2 due to R8 and R12. Its input is held midway between the input voltage and the voltage at B due to the dividing action of R6 and R11. The output of IC2b is therefore

$$2\left(\frac{-0.5+1}{2}\right)=+0.5\text{V}$$

The output between B and C is consequently 1V.

In the unbalanced mode with output C grounded, the feedback voltage via R10 no longer exists, so IC2a with its gain of 1 gives an output of -1V at B. If B is shorted to ground, the voltage at the non-inverting input of IC2b becomes +0.5 which is amplified to 1V and appears at C. Unfortunately, this balance is not so easy to achieve in practice, primarily due to component tolerances. To overcome this, a preset (RV1) is used to load one output more than the other until the balance is exact. This should be set so that both outputs are exactly the same level when measured with respect to ground. An easy way to make this adjustment is shown in Fig. 16.

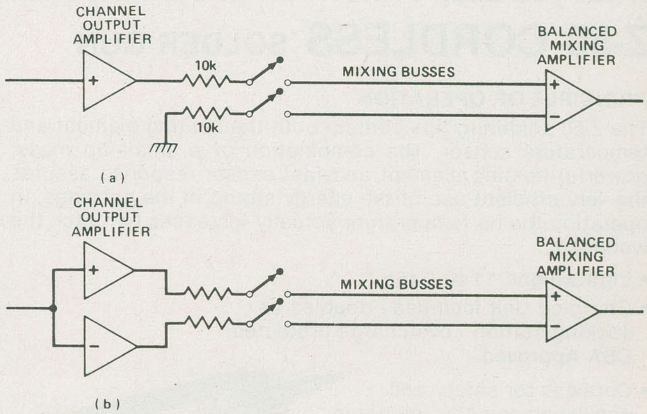

CHANNEL OUTPUT AMPLIFIER
+
10k
10k
MIXING BUSSES
BALANCED MIXING AMPLIFIER
+
−
(a)
CHANNEL OUTPUT AMPLIFIER
+
−
MIXING BUSSES
BALANCED MIXING AMPLIFIER
+
−
(b)

Fig. 12 Balanced mixer arrangements using (a) single-ended amplifiers and (b) balanced-output channel amplifiers.

So, now you know how to balance. The question remains, do you know what to balance? Any interconnection between two pieces of audio equipment can be balanced by the addition of a few op-amps, but it is rarely worth interfering with low impedance unbalanced connections which are carrying

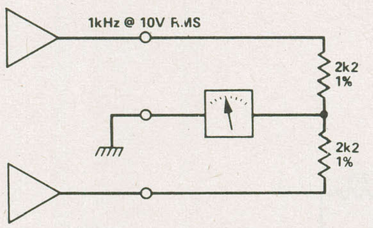

1kHz @ 10V RMS
2k2 1%
2k2 1%

Fig. 16. Adjusting the balance of the circuit shown in Fig. 15. RV1 is set to give a minimum output level.

high level signals over short distances – say less than 20 meters. Microphones should always be fed to balanced inputs, and it is also worth balancing pick-up cartridges and tape recorder heads. Connections between pre and power amplifiers are often improved by balancing, especially where ground currents from the power amplifier would otherwise find their way into the sensitive parts of the pre- amplifier and cause hum.

In brief, balancing can only bring about an improvement in a situation, so if you have more than your share of the dreaded hums give it a try.

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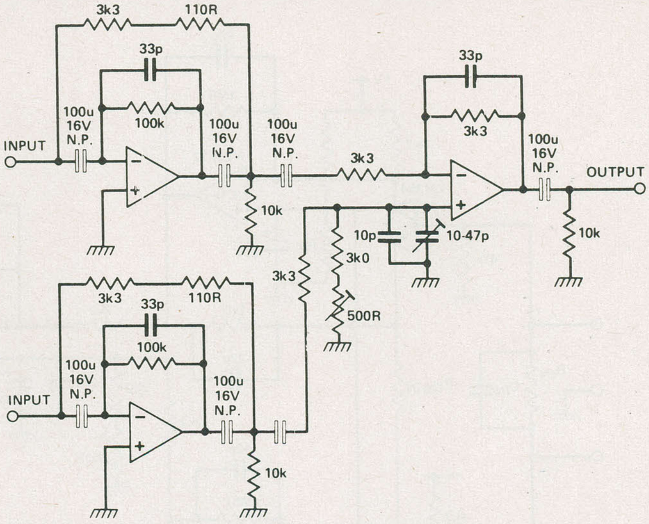
3k3
110R
33p
100u 16V N.P.
100k
100u 16V N.P.
100u 16V N.P.
INPUT
3k3
33p
3k3
100u 16V N.P.
OUTPUT
10k
10p
10-47p
3k0
10k
3k3
500R
3k3
33p
110R
100k
100u 16V N.P.
INPUT
100u 16V N.P.
10k

Fig. 13 A practical circuit for a balanced-input mixing amplifier.

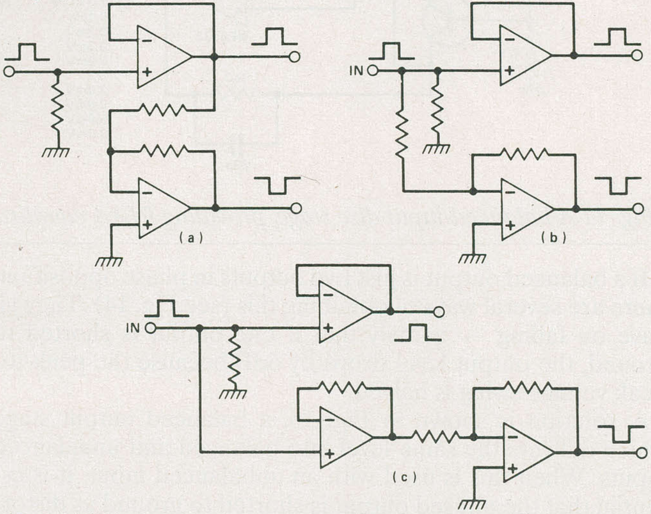

Fig. 14 Some differential (or balanced) output configurations.

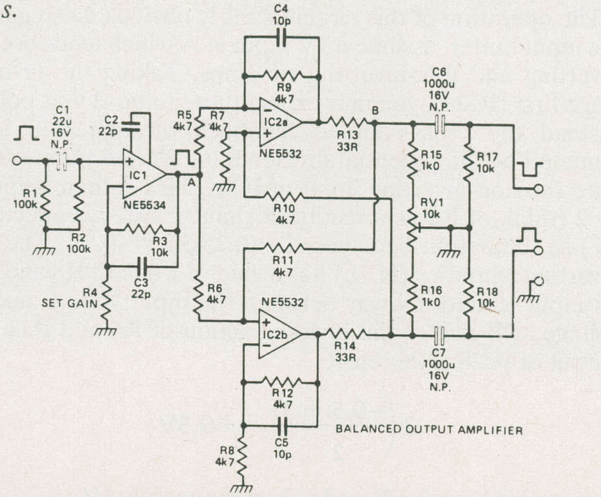
C4 10p
R9 4k7
C1 22u 16V N.P.
C2 22p
R5 4k7
R7 4k7
IC2a
NE5532
R13 33R
B
C6 1000u 16V N.P.
R15 1k0
R17 10k
R1 100k
IC1
NE5534
A
R10 4k7
RV1 10k
R2 100k
R3 10k
R11 4k7
R4 SET GAIN
C3 22p
R6 4k7
NE5532
IC2b
R16 1k0
R18 10k
R14 33R
C7 1000u 16V N.P.
R12 4k7
R8 4k7
C5 10p
BALANCED OUTPUT AMPLIFIER

Fig. 15 A balanced output amplifier. The cross-coupled feedback increases the output of either op-amp by 6dBm when the opposite output is shorted to ground, thus allowing the circuit to drive unbalanced inputs as well as balanced ones. ■

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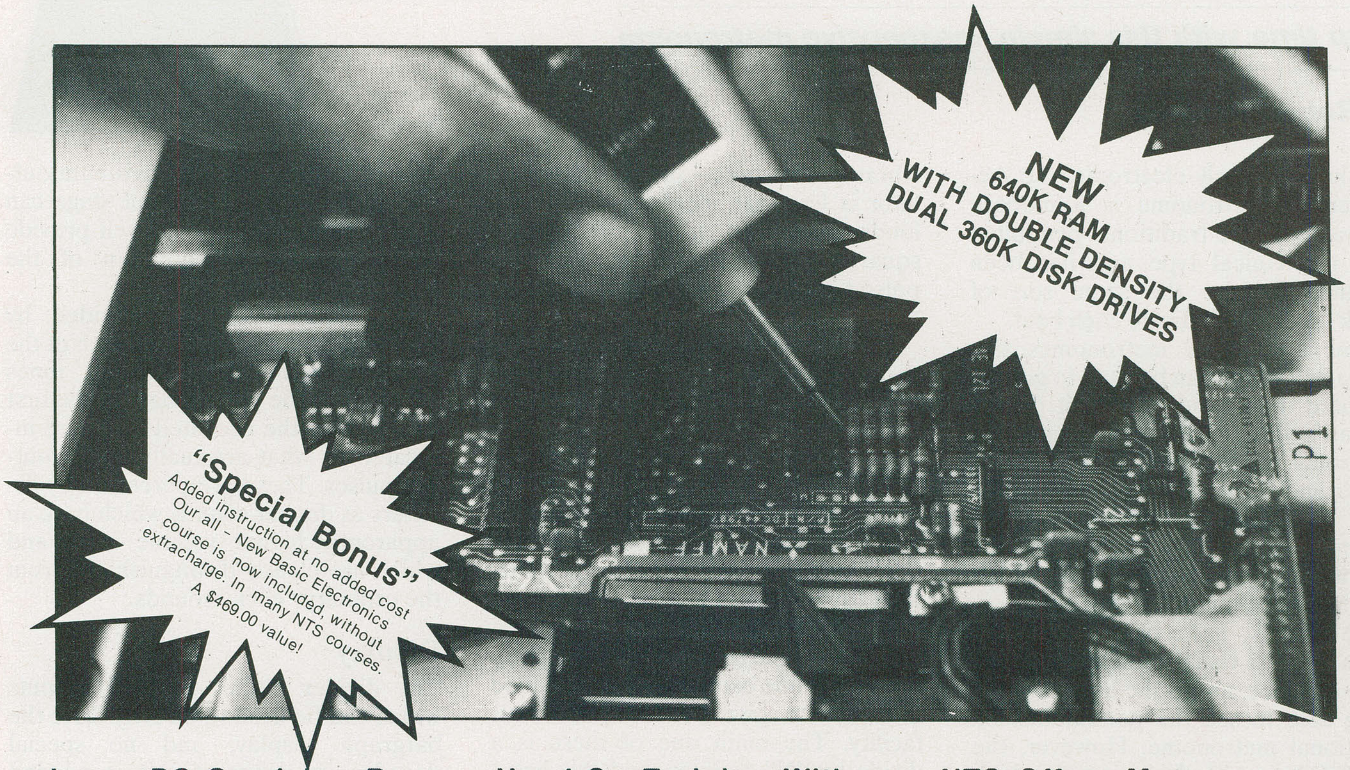

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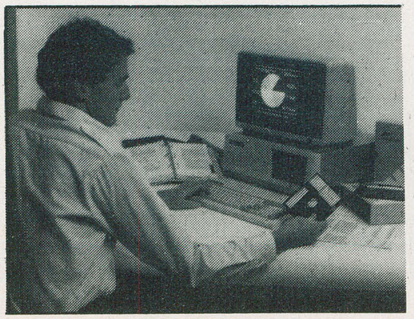

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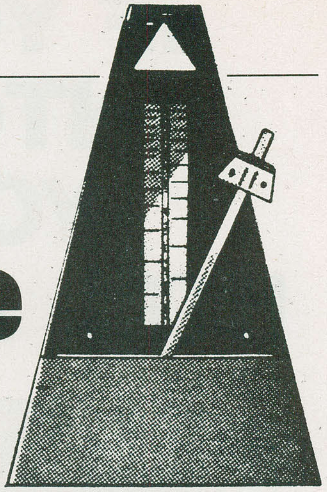
Accented Beat Metronome



Keep time with this simple, inexpensive metronome

By Robert Penfold

Although purely electronic, the Accented Metronome is a modern equivalent to the traditional pendulum style mechanical type and has been designed to give the same sort of "click" sound to indicate each beat.

Some mechanical metronomes also have a bell which can be used to give an accented beat and this unit has a similar facility. This is in the form of an additional circuit which enables a longer and deeper "thud" sound to be used to accent anything from every second beat to every tenth beat. The accentuation can be switched out altogether when it is not required.

The unit also has a bargraph display which gives a visual indication of the beat sequence, and is the equivalent of being able to see the pendulum of a traditional metronome. However, the ten LED bargraph shows exactly which beat is the current one in the sequence, even when, say, only every sixth or eighth beat is accentuated.

The unit is self-contained with power being provided by an internal 9V battery, and it is quite simple and inexpensive despite the fact that it provides both an accented beat facility and an LED display. It covers a wide beat range of around one every two seconds to about five per second.

System Operation

A clock oscillator, two monostable multivibrators and a digital divider circuit form the basis of the metronome, as can be seen from the block diagram of Fig. 1. The clock oscillator is a low frequency type which has its output frequency made adjustable by means of variable resistor. The frequency range covered by the unit governs the beat rate range of the metronome, and is therefore about 0.5Hz to 5Hz.

The output of the clock oscillator drives the input of a monostable multivibrator. The direct output of the oscillator is less than ideal for driving the loudspeaker as it is virtually a squarewave signal, whereas a short pulse signal is needed to produce each "click" sound.

The monostable is a non-retriggerable type which acts as a pulse shortener, and provides and output pulse of suitable duration regardless of how long the input pulse duration happens to be. The output pulses from the monostable are fed into a mixer circuit, and from here they are coupled to an output stage which provides the fairly high drive current needed to get good volume from the loudspeaker.

This gives the basic metronome function, but some extra stages are needed in order to give the accented beat facility. The main one of these is a divide by "N" counter, and this has a division rate which under switch control can be set to any integer from two to ten.

The output of the divider drives a second monostable multivibrator, but obviously this monostable will only be triggered on every second clock cycle, third clock cycle, or whatever the selected division rate dictates. The output pulses from this second monostable are mixed with the signal from the first one, but as the loudspeaker is already driven with the maximum output current that the output stage can provide, this does not in itself provide any significant accentuation of the basic "click" sounds.

The accentuation is provided by having the output pulse duration of the second monostable several times longer than the pulse length of the first one, so that the accented beats are indicated by what are really longer output pulses. These are perceived by listeners as deeper sounds which have an apparently higher volume level, and which are clearly distinguishable from the ordinary "click" sounds.

Display

The divider circuit has ten outputs which can be used to directly drive the bargraph display, and no special decoder or driver circuit is needed here. In fact the display is not a true bargraph type, which would have the first LED lit to indicate the first beat, LEDs one and two switched on to indicate the second beat, and so on.

This display operates in what is generally known as the "dot" mode, where the first LED. lights up to indicate the first beat, the second LED, (and only the second LED) switches on to indicate the second beat, the third LED turns on to mark the third

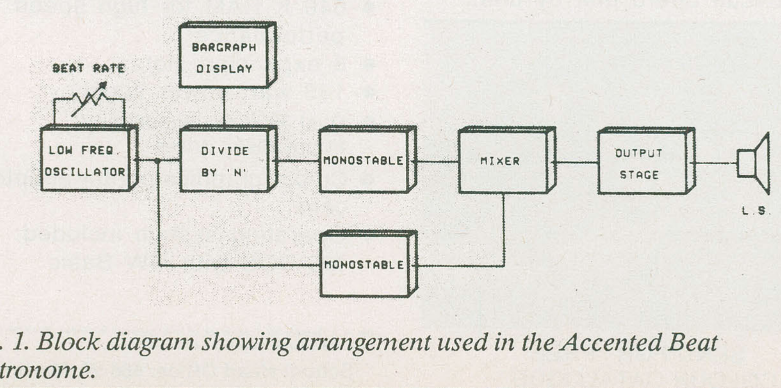


Fig. 1. Block diagram showing arrangement used in the Accented Beat Metronome.

beat, and so on. A "dot" type display perhaps gives a slightly less clear indication, but it is the only type that can be easily used with the driver circuit available in this case, and it also has the great advantage of providing the unit with a much lower level of current consumption.

Circuit Operation

The complete circuit diagram of the Accented Metronome appears in Fig. 2.

A 555 astable circuit generates the clock signal, but in order to keep the current consumption of the circuit down to an acceptable level a low power version of the 555 such as the 7555 is recommended for IC1. Potentiometer VR1 is the frequency control, or the Beat Rate control as it should more correctly be called in this case.

The timing capacitor C2 should be a tantalum bead component. An ordinary electrolytic type capacitor is considerably less than ideal for this application where the poor tolerance rating could give a frequency range which was well away from the desired one, and the high leakage level could result in even worse frequency accuracy or even the circuit failing to oscillate at all at the low frequency end of the range.

Both monostables are based on two of the CMOS 2-input NOR gates of IC3 and use what is a standard configuration. IC3a and IC3b have capacitor C3 and resistor R4 as their timing components, and the approximate output pulse duration is 0.2 milliseconds. This gives the higher pitched "click" sound. IC3c and IC3d have C4 and R6 as their timing components, and with an output pulse duration of about 0.8 milliseconds or so this gives the lower pitched "thud" sound.

The two sets of output pulses are mixed by resistor R7 and R8 which form a simple passive mixer circuit. The pulses drive TR1 hard into conduction so that a heavy but brief current is driven through the loudspeaker LS1.

The peak power level fed to the loudspeakers is actually quite high and constitutes a considerable overload, but as the output pulses are very brief and infrequent the average power fed to LS1 is quite low, and there seems to be no danger of it being damaged. A high impedance (about 64 ohm) loudspeaker would appear to be better suited to this type of output stage, and although loudspeakers of this type will work quite well in the circuit, they provide a substantially lower volume level than low impedance types.

Divider

The divider IC2 is a CMOS 4017BE, which is a decade counter and one of ten decoder. In this case the ordinary divide by ten ("carry out") output at pin 12 is of no interest and is ignored. It is the other ten outputs that are of use, and these are numbered from "0" to "9".

When the device is reset, output "0" goes high and all the other outputs take up the low state. On the next clock pulse output "0" goes low and output "1" assumes the high state. The next clock pulse takes output "1" low again and sets output "2" high.

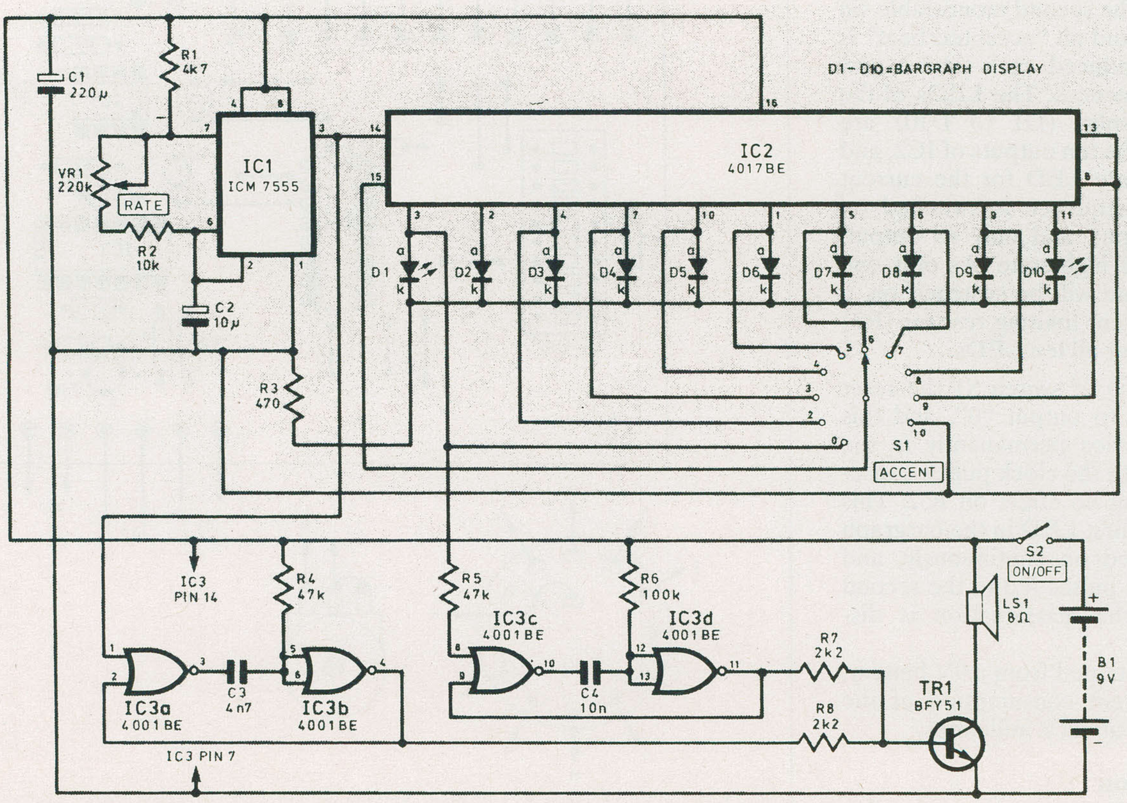


Fig. 2. Complete circuit diagram for the Accented Beat Metronome

This sequence of events continues until output "9" goes high. In the next clock pulse output "9" returns to the low state and output "0" goes high again. This takes things back to the beginning again, and the device cycles indefinitely in this manner.

At least, it does if it is allowed to. In this circuit the Reset input at pin 15 of IC2 is coupled by switch S1 either to one of the outputs, or in the tenth position it is simply tied to the 0 volt rail. It is therefore only in position 10 of switch S1 that IC2 provides the standard divide by ten action. In the other switch positions at some stage in the sequence the output to which the reset input is connected will go high, and IC2 will immediately be reset to the initial state where output "0" is high.

For example, in position 2 output "0" will go high in the normal way, followed by output "1" on the next clock cycle. However, when output "2" goes high IC2 is reset and output "0" goes high again. A divide by 2 action is therefore obtained, and by selecting the appropriate switch position any division rate from two to ten can be obtained.

The "0" output of IC2 is coupled to the input of the second monostable via resistor R5, and an "accented beat" is therefore produced each time a new cycle recommences. The LEDs of the bargraph display (D1 to D10) are driven from the ten outputs of IC2, and the appropriate LED for the current beat in the sequence is switched on since its output, and only its output, will be in the high state. As only one LED at a time will be switched on, a common current limiting resistor (R3) can be used for all ten LEDs.

In position 0 of switch S1 the reset input is tied to output "0", and this holds the device permanently in the reset state with the clock pulses consequently having no effect on IC2. This results in the first LED in the bargraph being switched on continuously, and with no input pulses fed to the second monostable the accentuation is disabled.

Power is obtained from a 9V battery, and the current consumption of the circuit is only about 8 milliamps.

Construction

Although this is potentially a rather awkward project, the printed circuit design and component layout shown in Fig. 3 helps to make matters much more straightforward.

Construction of the board is not difficult, but bear in mind that IC2 and IC3 are both CMOS types, and that the normal anti-static handling precautions should be observed when dealing with these. This basically means using integrated circuit holders for these components, and not fitting them into place until the unit has been completed in all other respects.

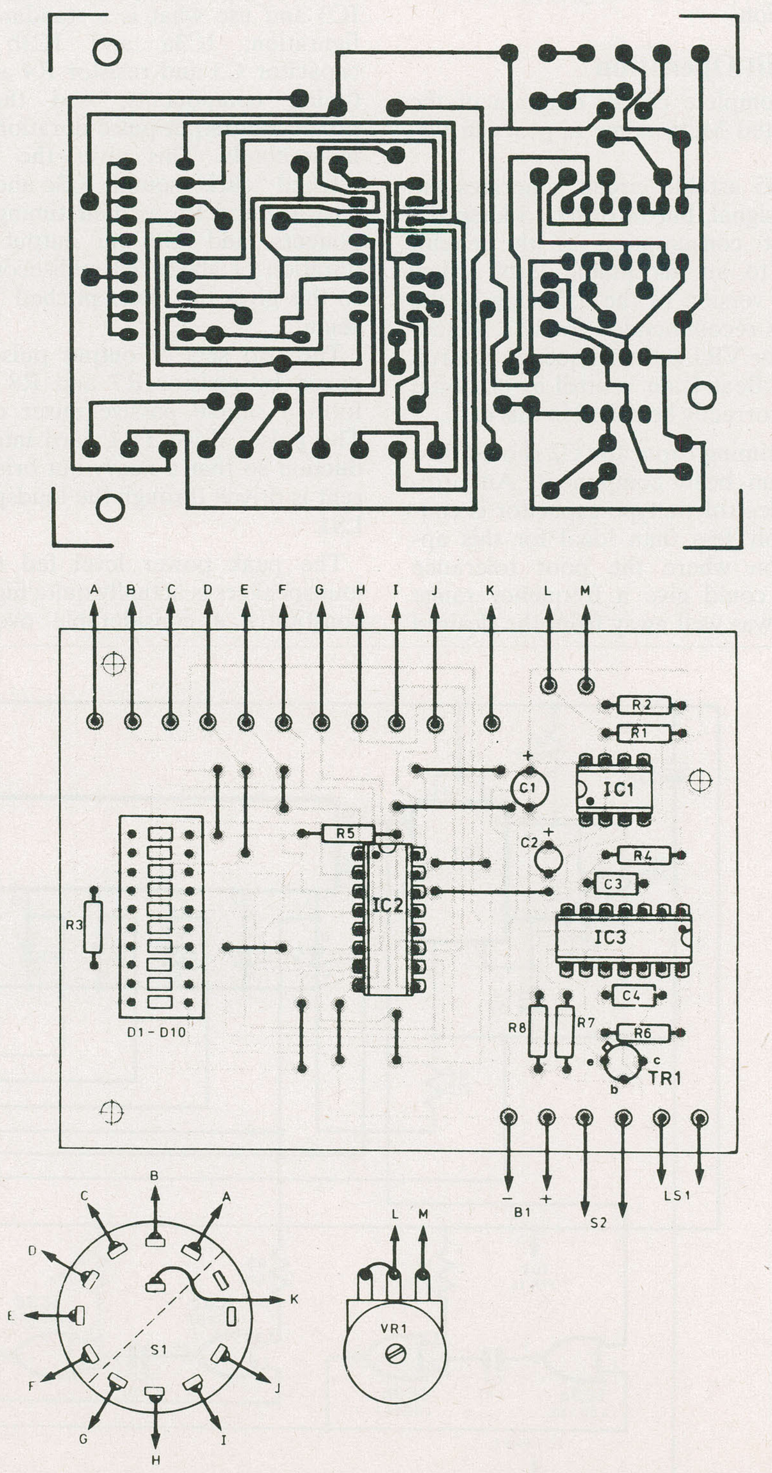


Fig. 3. Full size printed circuit board master foil pattern (top), component layout and interwiring for the metronome. Note that a 20-pin DIL socker must be used for mounting the bargraph display.

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Although IC1 is also a CMOS device, it does not require any special handling precautions as it has very effective internal protection circuits which render them unnecessary. As the 7555 integrated circuit is very inexpensive, it is recommended that an IC holder is used for IC1.

It is assumed in Fig 3. that the bargraph display is of the type which has a 20-pin DIL package, and this will plug straight into a 20-pin DIL integrated circuit holder mounted on the board. This socket is not just needed to prevent possible heat damage to the device when fitting it into circuit, but is also required to physically raise the display to as more suitable height. The socket should *NOT*, therefore, be omitted.

With this type of display there usually seems to be nothing to indicate which way it should be fitted, but if necessary the correct orientation can be found by trial and error, and the display will not sustain any damage if it is fed with power of the wrong polarity.

Of course, if preferred the bargraph display can be formed from ten ordinary panel mounting LEDs fitted on the front panel of the unit, and this could actually give a much clearer display. On the other hand, it would increase the amount of hard wiring required and would make construction of the unit much more difficult.

Case

The case used for the prototype is a plastic type having an aluminium front panel and approximate outside dimensions of 205mm by 145mm by 40mm. The unit could actually be fitted into a much smaller case if desired, although this might necessitate the use of smaller loudspeaker with a consequent reduction in volume, and it could prove difficult to mount the printed circuit board in a way which brings the display into a suitable position.

Assuming that the metronome is built along the same lines as the prototype, the three controls are mounted on the front panel and the loudspeaker is fitted towards the left-hand side of the top panel or case "lid".

A speaker grille of some kind is needed, and the most simple way of producing one of these is to drill a matrix of holes about 5 millimeters in diameter. Be very careful with the placement of the holes though, as it is not quite as easy to make a neat job of this as one might think.

Miniature loudspeakers rarely have any provision for screw fixing, and it is normally necessary to glue them in place. Any good general purpose adhesive will do, but try to avoid smearing any onto the diaphragm.

The printed circuit board is mounted on the base panel towards the right-hand side of the unit, and it is mounted on spacers which give a stand-off about 20 millimeters from the base panel. This is to bring the display to a suitable height, so that it is immediately underneath a display window cut at the appropriate position in the top panel of the case.

The rectangular cutout can be made using a coping saw or a fret saw. A piece of red display window material is glued in place behind the cutout.

To complete the metronome the hard wiring is added, and this shown in Fig. 3. The wiring from the board to the Rate control (VR1) and the Accent switch (S1) is carried out by wiring from point "A" to point "A" and then the two point "B"s are connected together, and so on. Ordinary multistrand connecting wire is used and there should be no real difficulty here provided the pins, component tags, and the ends of the leads are properly tinned with solder prior to making each connection.

There is ample space of the battery, and this can be held in place with a double-sided adhesive pad. If six 1.5V batteries in a holder are used, a standard 9V style battery clip is needed to make the connections to the holder.

In Use

Give the finished unit a thorough check for errors before switching it on and testing it. Once switched on it should produce a regular "clicking" sound at the rate controlled by VR1, and by setting S1 to introduce the accentuation the appropriate sounds and responses from the display should be obtained. If there is any sign of a malfunction, switch off at once and recheck all the wiring.

If the metronome is to be adjusted "by ear" there is no need to mark a scale around the control knob of VR1, but many users will require some sort of beat rate scale. There is no real difficulty in finding calibration points by counting the number of beats in a certain period of time, and using trial and error to fine tune VR1 to the correct settings. These can then be marked using rub-on transfers.

It can be difficult to make a really accurate scale as the calibration points tend to become cramped at the high frequency end of the range. This problem can be eased by using a "logarithmic" potentiometer for VR1 and connecting it in reverse so that clockwise adjustment gives a reduction in the beat rate. This gives something approximating to a linear scale but it is reverse reading of course.

Using a large control knob also helps to space out the calibration points and make precise adjustment easier.

Parts List

Resistors (All 1/4W, 5% carbon)

R1	4k7
R2	10k
R3	470R
R4,5	47k
R6	100k
R7,8	2k2

Potentiometer

VR1	220k

Capacitors

C1	220u radial 10V elect.
C2	10u 16V tantalum bead
C3	4n7 polyester
C4	10n polyester

Semiconductors

IC1	7555 CMOS Timer
IC2	4017 decade counter
IC3	4001 quad 2-input NOR
TR1	2297 npn silicon
D1-D10	10 LED bargraph

Miscellaneous

S1	12-way, 1-pole rot. with stop
S2	Sub-min SPST toggle
LS1	8 ohm loudsp. 76mm diam.

Case: 250mm x 145mm x 40mm; PCB; 8-pin, 14-pin, 16-pin, and 20-pin DIL IC holders; 9V battery and clip; red display window material; 2 control knobs; solder pins; wire; stand-offs etc.

■

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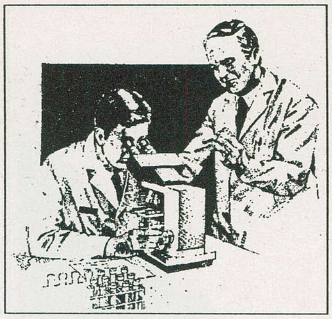

The Scientists Tell Me...

By David P. Dempster

Superchips on the Way

A newly developed technology called CMES (Complementary Metal Semiconductor), which could lead to the production of a superchip, has been introduced by a group of researchers under Professor Per Arne Tove in the Department of Technology at Uppsala University in Sweden. Because of its sensitivity to radiation the superchip is considered most suitable for use in space research and medical applications.

The new technology has a low power consumption, only about 1/100 of CMOS (Complementary Metal Oxide Semiconductor), due to lower voltage supply. It is much less sensitive to static electricity or radiation and it allows for even higher density VLSI (very large scale integration) than previously. It may be used for both analog and digital techniques.

The noise is reduced as carriers do not move as close to the surface as they do when CMOS is used and it is faster than in- polar technology. The lack of gate oxide also means that oxide problems like hot-electron effects are minimized.

Apart from being more suited than conventional CMOS to aerospace technology, test results also show a promising prognosis for use in nuclear detectors. This is due to the radiation-hard and low- noise properties and in electronic circuits placed at a high voltage with power supply via an optical fibre.

It would be equally useful in circuits for implantation in the human body like hearing aids where the low power consumption means longer battery life, and in applications in mobile radios and telephones as well. It would also be possible to improve the standard of tiny transistors without the problem of gate oxide.

In theory, production should be easier using the CMES concept, but in practice, about another year of development work is required before that stage is reached, according to one of the researchers.

Immune System Probed With Laser Microscope

At the University of Toronto a modern day Sherlock Holmes is using sophisticated technology to probe the mysteries of how cells recognize one another.

The detective is Professor Tania Watts and the technology she is employing is a custom-built laser-microscope. With the knowledge gained, scientists will be better able to understand autoimmunity and diseases such as AIDS and cancer.

Professor Watts, who is an immunology specialist, is particularly interested in T cell activation in the immune system, the body's battle zone with foreign agents. Two major components of the immune system, B cells and T cells, produce antibodies to foreign materials (antigens) that invade the body. B cells can recognize antigen directly, but this is not so with T cells. The latter cells only recognize foreign matter when it "piggybacks" on another cell such as a B cell or an antigen presenting cell. @INDENT = Small is very small in Watts world. That which Watts scrutinizes comprises foreign antigens, proteins called major histocompatibility complex (MHC) proteins and T cell receptors (the part of the T cell that recognizes both antigens and MHC proteins). All three play a role in cell recognition and Watts studies how these three components interact during T cell recognition.

When she was a research fellow at Stanford University in California, The young scientist became acquainted with a sophisticated machine, called a laser-microspectro-flurometer, which is used specifically to examine cell recognition events. The custom-designed unit now gracing her lab of U of T, the second one in all of North America, is her own handiwork — assembled from scratch by Watts.

So that she can study the glimmer of recognition that occurs when two cells meet, she first prepares a membrane solution consisting of a lipid bilayer containing purified MHC proteins. This a simplified version of a B cell surface and it is used to coat a glass slide. Then a fluorescent foreign antigen is allowed to bind to the glass supported membrane. At this point, Watts places a prism on top of the glass slide before positioning it in the microscope portion of the machine.

By directing a focused laser beam into the prism, laser light provides total internal reflection onto the glass supported membrane and allows her to examine the fluorescent molecules nearest the model membrane.

"By adding a second cell, a T cell, to the model membrane and using the laser to illuminate the region of contact between the T cell and the antigen cell, we are trying to infer what is going on when two cells recognize each other," says Watts.

Next on the schedule is an attempt to purify the T cell receptor in an effort to create a complete model system. "If we can regenerate the same binding activity with only components of the cell, then we can say we've identified all the components in the cell that were responsible for the recognition event," she commented.

She knows from her studies that only 1,000 molecules (an extremely small number) are needed to stimulate the T cell to release the hormone Interluken 2. What isn't known is which amino acids on a foreign antigen bind to which amino acids on the membrane proteins. It's the biochemical details on the binding action that she is trying to work out.

According to Watts, her research can be applied to any situation in which one cell recognizes another cell, such as embryogenesis and neural development, and any places in the body where cell-to- cell adhesion takes place. Ultimately, her research will lead to the development of better and more effective vaccines.

Funding for Watts research is being provided by the Medical Research Council of Canada and the National Cancer Institute.

Keeping Cool With The Sun

Using the sun to run a refrigerator isn't exactly new. What is new is the approach taken by a French firm, Brissoneau & Lotz Marine. Their system has no moving parts and with no moving parts, there is no friction and in the absence of friction there is no wear.

Conventional solar refrigeration systems employ DC power generated by solar cells to run the motor that in turn drives the system's compressor. However, with the French system there is a difference. Refrigeration is achieved by heating and cooling methanol, using the adsorption of methanol on activated carbon. The micro particles of carbon provide a very large exchange surface, due to their surface geometry.

How does it all work? Simple, really. The cooling cycle begins after sunset when the container of activated charcoal, adsorbs methanol from a reservoir. the very thin layer of methanol quickly evaporates, creating a cooling effect. This, in turn, causes the temperature to drop below freezing.

During the daytime hours the cycle is reversed and solar energy heats the charcoal, driving off the methanol as a vapor. This vapor condenses and is collected in the reservoir where it is again ready for the next cooling cycle.

The refrigerator has four main subassemblies: a solar collector, a stainless steel evaporator, a water reservoir, and an insulated section containing the evaporator and an optional ice cube maker. Also, there is a special ice producing model, the Gaspard CGI, which, it is claimed, can supply 11 pounds of ice per day.

So, if you're stuck beyond the reaches of the power company, this refrigerator may be the answer to keeping medicines or foods preserved efficiently, effectively and at low cost. The company states they can construct refrigeration warehouses by combining multiple refrigeration units inside the structure that are operated from roof-mounted solar panels.

Brissoneau & Lotz Marine has indicated they are interested in a joint venture with a Canadian company. Firms interested in exploring this subject may contact the company at B.P. 4, rue de la Metallurgie, 44471 Carquefou Cedex, Nantes, France, Tlx 710 747, Fax (33) 40 30 30 23 Tel. (33) 40 30 10 50

The Future Of Plastics

Biodegradable, environmentally safe plastics for use in surgical sutures, artificial limbs, and casings for time-released drugs and pesticides can be developed from lactic acid, an underused organic chemical.

According to Edward S. Lipinsky of Battelle Memorial Institute's Columbus (Ohio) Laboratories, lactic acid is unique because it can be directly converted into polyesters, and because it can be produced from materials as diverse as corn, sugar cane, wheat, barley, coal, petroleum and natural gas liquids.

Citing their high strength, adaptability and biodegradability, Lipinsky suggests that plastics produced from lactic acid should prove especially useful in pharmaceutical and medical applications. The biodegradability of lactic acid polymers makes them well-suited for prosthetic devices in repair and reconstruction of traumatic wounds, states Lipinsky. He says the materials can replace steel plates and pins, allowing the bone to remodel stresses naturally as the polyesters gradually reabsorb.

Unfortunately, all is not roses. Lapinsky admits that lactic acid has certain weaknesses which have impeded its growth as a polymer source. Because it is produced by fermentation, lactic acid is difficult to obtain in the high purity required for commodity polymers.

The current availability and relatively low prices of petrochemicals have discouraged development of lactic acid processing. It won't always be so, says Lipinsky, and he says now is the time for the chemical process industry to initiate research into using a lactic acid starting material for resin products. In fact, he sees lactic acid as a sleeping giant just awaiting to be nudged in wakefulness when petrochemicals are hit by rising petroleum prices or shortages.

Missing Micros

The course in microprocessors promised for this issue has been delayed by production problems. It will be featured in next month's issue, along with a survey of the various training kits available.

Mini-Review: Cordless Soldering Iron

A new rechargeable soldering iron is on the market from Zimac Laboratories of Quebec. Eight nickel-cadmium batteries provide 50 watts to the unit, which is kept at full charge by the charger/holder. The iron's main advantage lies in the small tip mass and fast-response sensor located close to the tip's end, allowing most efficient use of the stored energy. The temperature can be adjusted from 550 to 750 degrees F.

Full heat from a cold start took less than ten seconds, and once warm, recovery after soldering was typically 1-2 seconds. The power control was impressive: we soldered solid 14-gauge copper wire easily, and then used the iron to solder delicate PCB traces. The iron matched itself to the job flawlessly. It would be ideal for field work because it can handle just about any soldering job you'll come across.

Operating time is about 3/4 hour depending on the workload, and full recharge time is about four hours (overcharge protection is provided). The iron weighs 11 ounces or 315 grams. Different sizes of tips are available.

The iron, charger and one tip are $149.95 from Ground Plus Electronics, PO Box 607, Aurora, Ontario L4G 4J9.

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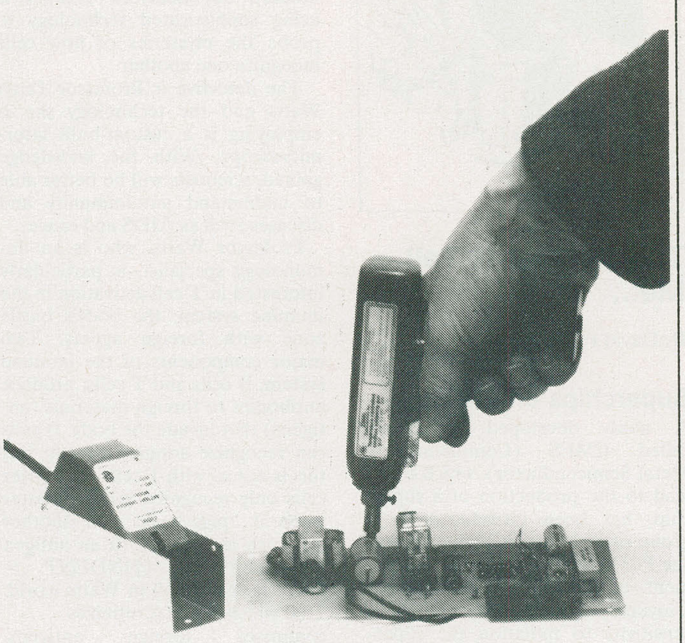

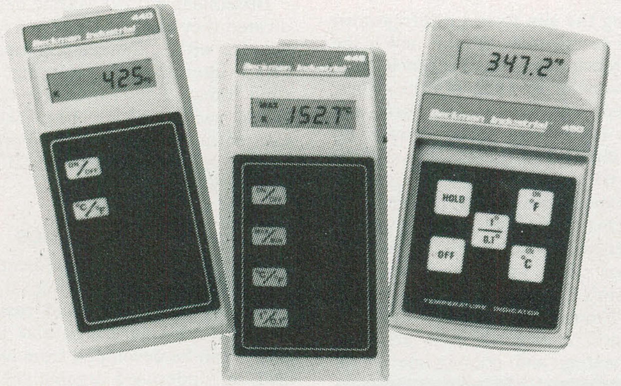

Handheld Thermometers

The 400 series of Beckman handheld thermometers offer fast response coupled with high repeatability in surface, air or immersion measurements.

The Model 450K sports a 2,000 hour batter life while models 400K and 440K feature "Auto-Off" to extend battery life.

Interchangeable probes simplify use and provide a versatile system with one basic model. Probes are available in Type K thermocouple, platinum RTD and thermistors types.

The Model 440K features ±0.3% accuracy, 1° resolution and switchable °F/°C. The 445K has an accuracy of ±0.2%, 1°/0.1° autoranging and a Min/Max reading.

The 450K, 450PT and 450TH feature ±0.1% accuracy, 0.1° resolution to 399.0°F (203°C) and Data Hold. These units are also capable of using Type J,K,T,E thermocouples, Platinum RTD or thermistor types.

For more information on the 400 Series of Beckman thermometers contact BCS Electronics, 980 Alness Street, Unit 7, Downsview, Ontario M3J 2S2 (416) 661-5585.

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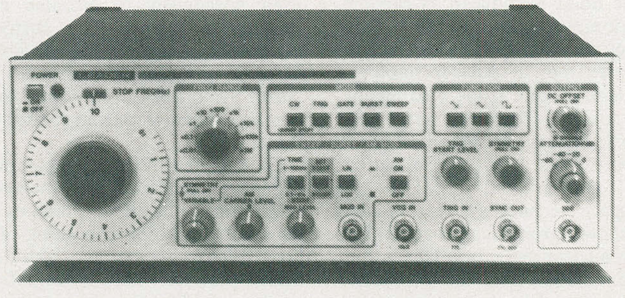

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Versatile output controls enable all types of signal conditions to be established such as different bias levels for amplifier work. The outputs may also be frequency or amplitude modulated by an external signal.

For more information contact Omnitronix Ltd., 2410 Dunwin Drive, Unit 4, Mississauga, Ontario L5L 1J9 (416) 828-6221.

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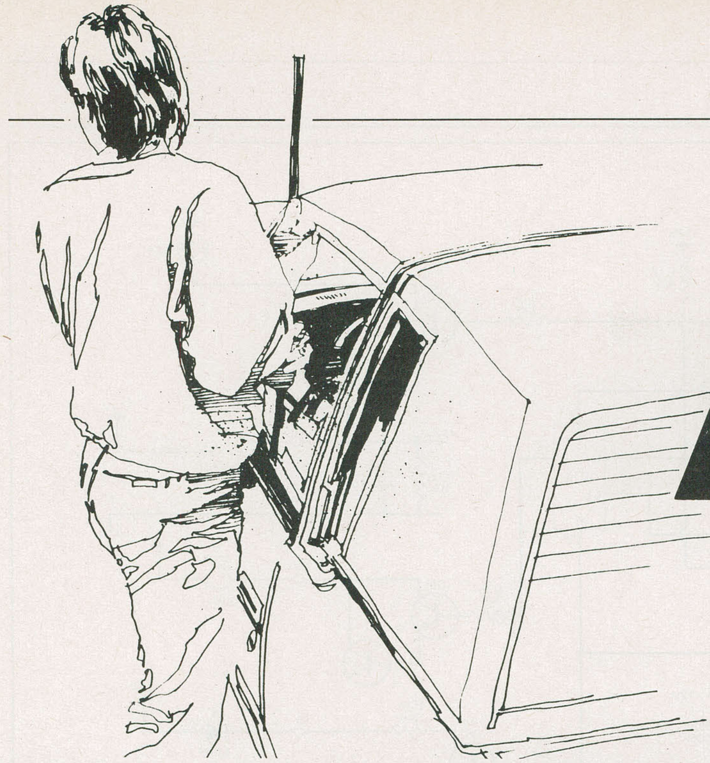


Car Alarm

Protect your car and its contents with this cheap and simple alarm

By Bob Noyes

The number of car thefts increases daily and the old adage 'lock it' is a little outdated as car thieves seem to be able to open, steal from or even drive away just about any car they choose.

In order to protect what is probably the second largest investment the average family makes, some further protection is required.

Auto theft, as the police call it, takes two forms – breaking into a car to steal from it (commonly for items such as cassette decks etc) and the actual theft of the car. Some protection against both is necessary.

Although at first glance, these requirements seem simple enough, other practical factors need to be considered which complicate the issue – for instance how to switch it on and off. Drilling holes in the outside bodywork of the car is out of the question because this tends to introduce rust round the switch. It will also get spattered with mud and spray from passing vehicles making the switch inoperative after a time.

Magnetic key fobs and infra red controllers, at first glance look like a possible way of actuating and deactuating from outside the car, but in practice needs to be used in one position around the car and this is not always easy when parked in awkward places. Both systems add to the time taken by the driver to gain access to the car, something not appreciated in the rain.

The only practical way is a delayed exit and entry but this can introduce a period when a would-be car radio thief has broken in and started hacking away at the wiring of the radio before the alarm sounds. Although the radio is unlikely to be removed in this time, a great deal of damage can be done.

The alarm described here is of the delayed entry and exit type but has the added advantage that when the alarm has been tripped by opening the door or trunk an internal buzzer sounds. This, although not very loud, indicates than an alarm has been set off and something else is about to happen. This should be enough to deter a thief as the last thing he wants is to be seen around a car with an alarm sounding.

Another important factor in an alarm is what form the output takes. Most commercial alarms sound their horns and lights intermittently. This, although very effective, doesn't do much for the horn, lights or battery as these draw an enormous amount of power and are usually controlled by a relay whose contacts arc and spark when switching these currents.

The contacts can weld themselves together sounding the horn and the lights continuously until the battery is flat. The alarm timer which all alarms must have cannot cancel a welded relay! As well as the possible damage because of the high currents, thick and bulky hard to handle wires need to be used. For safety, the alarm switch should switch off all power to the alarm and the supply to the lights and horns used when controlled by the alarm. This would mean a switch capable of 25A or so and not many alarms on the market supply such switches.

To eliminate this problem the sound output is generated by rotary siren having a maximum current consumption of 1.2A. This allows the whole installation to be fused at 2A so much thinner wires can be used.

As a secondary line of defence, the car can be immobilized when the alarm is switched on. One of two methods can be used. If the car is fitted with standard mechanical points, a capacitor can be switched in across them. The value should be in excess of 22u but with a working voltage of 600V or more. This is switched into circuit by an independent set of contacts on the alarm switch.

In most modern cars an optical or magnetic sensing system is used in place of the points. In these cases it is best to leave well alone as damage can be caused by connecting a capacitor in the wrong place so a switch is placed into the 12V supply side of the electronic ignition module. This can be found using a meter or by following the cars' circuit diagram. Again it is wired back to the alarm key switch.

Operation

On leaving the car the alarm is activated by the key switch. This allows about seven seconds to get out and shut the door. After this time the alarm becomes active and is indicated by the exit delay LED extinguishing (it comes on when the alarm is switched on). The alarm is now active and opening the

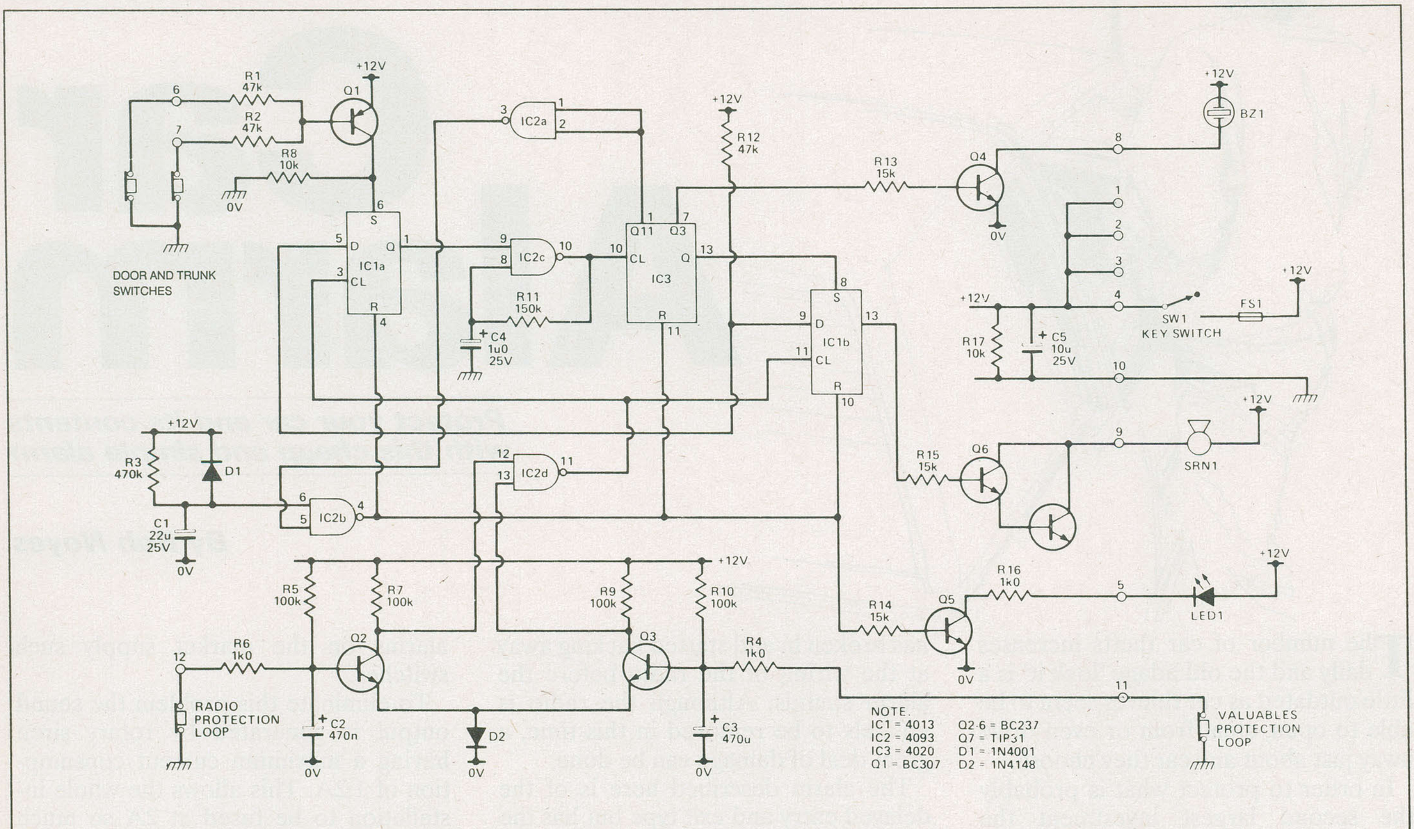

+12V
R1 47k
R2 47k
R8 10k
Q1
6
7
0V
DOOR AND TRUNK SWITCHES
IC1a
S
D
Q
CL
R
IC2a
IC2c
R11 150k
C4 1u0 25V
IC3
Q11
Q3
CL
Q
R
R12 47k
R13 15k
Q4
0V
IC1b
S
D
CL
R
BZ1
SW1 KEY SWITCH
FS1
R17 10k
C5 10u 25V
IC2d
R3 470k
D1
C1 22u 25V
IC2b
R15 15k
Q6
SRN1
R16 1k0
LED1
R14 15k
Q5
R5 100k
R7 100k
R6 1k0
Q2
RADIO PROTECTION LOOP
C2 470n
D2
R9 100k
R10 100k
Q3
R4 1k0
C3 470u
VALUABLES PROTECTION LOOP
NOTE.
IC1 = 4013
IC2 = 4093
IC3 = 4020
Q1 = BC307
Q2-6 = BC237
Q7 = TIP31
D1 = 1N4001
D2 = 1N4148

Fig. 1. the circuit diagram of the car alarm.

door will start the following sequence which once started cannot be stopped by shutting the door. Only the key switch will stop it.

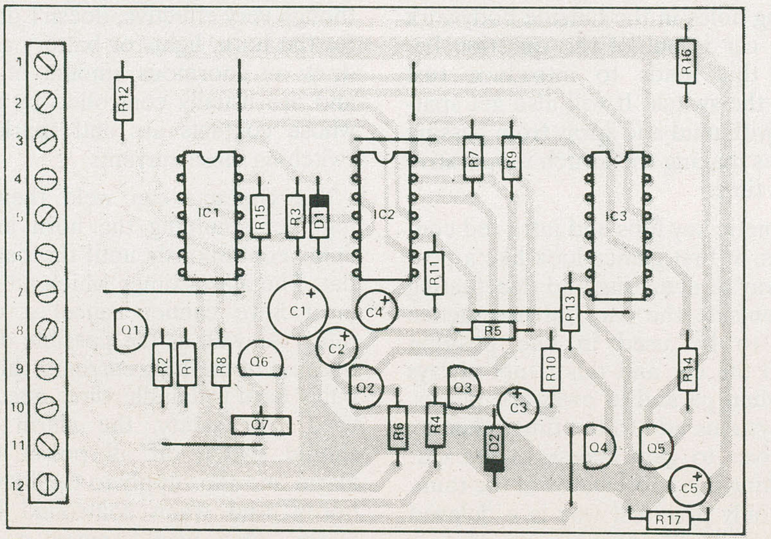
The internal buzzer sounds eight times over about a five second period. During this time the alarm should be de- activated by the key switch. Failure to do this will sound the main siren. The siren sounds for approximately one and a half minutes. It will then shut off and reset the alarm. If the door is left open the sequence will start again and will not stop unless the key switch is turned off or the door is shut and then only at the end of the sequence.

If the radio or any other equipment is tampered with and the ground connection removed, the siren will sound immediately.

Instead of the radio, a trailer can also be protected when connected to a car and parked. A loop connection is made around the trailer frame. This can be made with a plug and socket arrangement in such a way that the plug must be removed or the wires cut in order to steal the trailer. In both cases, the alarm will sound instantly. Of course provision must be made to short the wires together when the trailer is not being towed. This can be achieved with a shorting plug kept in the socket when not protecting the trailer.

The same method can be used to protect such articles as cases and the like carried in the car. The set up must be that to remove the protected articles, the plug must be undone or the cable cut, similar to the type of thing used in shops to protect goods on view.

Although primarily intended for cars, this alarm is ideal for RV trailers as the CMOS integrated circuits draw very little current and can be left on for several months without flattening the battery. The delayed circuit can be fitted to the main doors. The instant circuit can be connected to the wind up leg of the RV so that with the leg down the contacts are made (use a mercury tilt switch). When the leg is wound up to drive the RV away the tilt switch


1
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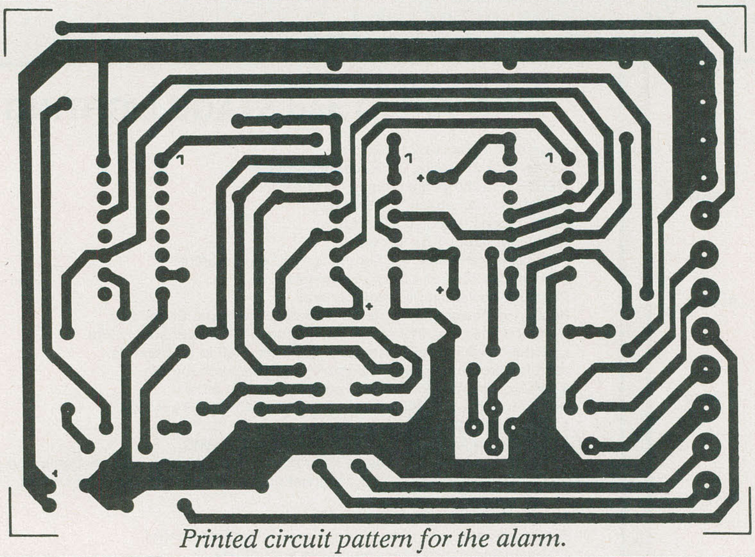
R12
R16
IC1
R15
R3
D1
IC2
R7
R9
IC3
R11
C1
C4
C2
Q1
R2
R1
R8
Q6
Q7
Q2
R6
R4
Q3
D2
C3
R5
R13
R10
R14
Q4
Q5
C5
R17

Fig. 2 The component overlay of the alarm PCB.



Printed circuit pattern for the alarm.

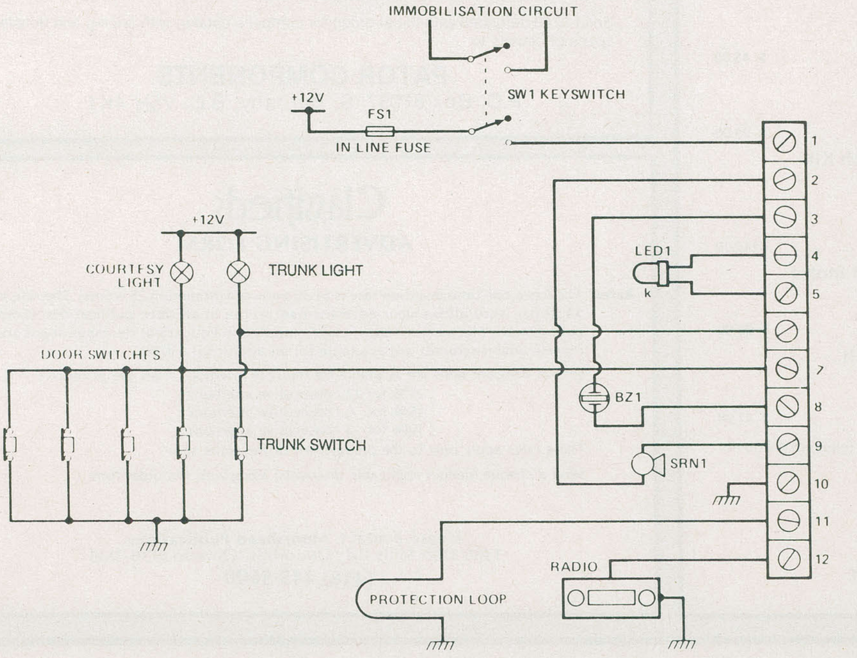


Fig. 3. Installing the alarm.

Parts List

Resistors (all 1/4W, 5%)

R1,2,12	47k
R3	470k
R4,6,16	1k0
R5,7,9,10	100k
R8,17	10k
R11	150k
R13-15	15k

Capacitors

C1	22u 25V tantalum
C2,3	470n 25V tantalum
C4	1u0 25V tantalum
C5	10u 25V tantalum

Semiconductors

IC1	4013
IC2	4093
IC3	4020
Q1	2N6015
Q2-5	2N5825
Q6	TIP31
D1	1N4001
D2	1N4148
LED1	Red Led

Miscellaneous

BZ1	12V Piezo Buzzer
FS1	2A inline fuse
SRN1	12V siren or bell
SW1	DPDT Key Switch

PCB; plastic case, connectors and cable; 12 way terminal strip; extra switches on doors and trunk if necessary; nuts and bolts.

contacts open and set off the alarm immediately.

How It Works

Fig. 1 shows the full circuit diagram of the alarm. When the alarm is on and the exit delay timed out, opening any one of the doors or trunk will close the light switches and turn on Q1 via R2 or R1. This produces a high on IC1a and will set the latch causing the output to go high starting the oscillator (IC2c) which runs at about 25Hz. Pulses from this are fed to a binary counter IC3, the outputs of which control the following sequence of events. After eight pulses from the oscillator, Q3, goes high and is high for eight more pulses before going low and repeats this throughout the sequence. The Q3 output is taken to Q4 via R13 to give current amplification and power a small buzzer. This is the internal buzzer which sounds eight times before the main siren. After 128 clock pulses, Q7 goes high and sets latch IC1b. This is the siren latch, and when set it causes the siren to sound via R15 supplying Q6, Q7 which are wired in a Darlington configuration.

After a total 2048 clock pulses, Q1 1 becomes high which is inverted by IC2a. The resulting low on IC2b causes a short reset pulse which resets IC1a, IC3 and IC1b. The alarm has now gone through a complete sequence and is ready to be set off again should the need arise.

The delayed exit is produced by IC2b. After switch-on C1 is slowly charged via R3 while charging IC2 pin 4 is high. This turns on Q5 via R14 to illuminate the exit LED via its current limit resistor R16. When C1 has charged to about eight volts, this will cause pin 4 to fall to 0 volts, a high must appear on pin 5 due to the counter being rest causing a low on Q1 1 which is inverted by IC2a.

The delay exit time may be increased by increasing the value of R3. D1 provides a discharge path for C1 when the alarm is switched off. R17 provides the load for the discharge path.

The delayed entry is provided by the 128 clock pulses required to set the siren state during which time the alarm should be turned off. By this method of sequencing various time configurations may be achieved by simply selecting the outputs from IC3 to lengthen or shorten the timings. For example, taking the rest from Q1 1 (pin 1) to Q1 2 (pin 2) will double the length of time the siren sounds to nearly three minutes.

continued on page 54

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Hi-Fi Power Meter

Build this inexpensive power meter for your audio systems

By Paul Chappell

When faced with the task of designing a power amplifier, the variety of different approaches that can be taken is almost overwhelming.

If the load to the amplifier is known, the power can be derived from the voltage alone. The very simplest method is to assume that the load is a pure resistance, to rectify the output voltage and apply it to a single quadrant square-law circuit, (since power is proportional to the square of the voltage for a given resistive load) and then to smooth the output and use it to drive a meter.

If the meter movement is sensitive enough, the entire circuit can be made from passive components and will divert very little power from the loudspeakers.

This approach relies for its accuracy on two factors. First of all it assumes the loudspeaker impedance is close enough to a pure, fixed resistance for the assumption to be valid. The second assumption is that a reasonably accurate square-law circuit can be made. In practise, reasonable results can be achieved, and this type of design has the advantages of being simple, cheap and reliable. A practical circuit along these lines will be given later on.

This is all very well for PAs, music centres and the like but for top flight hi-fi or for accurate power monitoring, something considerably better is called for. If the current is measured as well as the voltage, there is no need to make any assumptions about the loudspeakers. The circuit can take into account the characteristics of the load. But how?

What do we do with the current and voltage signals when we've got them? Multiply them? Find the RMS values and multiply? Find the average and multiply? It depends on exactly what we're trying to measure – which is not as silly a question as it sounds.

Power To People

For a resistive load there's no doubt about what we want to measure. However, for a load with a reactive component the case is not so clear cut. Fig. 1a shows the voltage, current and instantaneous power waveforms for a resistive load with a sinusoidal voltage applied. The power (p) varies from a peak when v and i are both at peak positive or negative values down to zero when v and i are both zero. However, it is always positive.

The average power delivered to the load is shown by the dotted line. This is the mean value of the instantaneous power curve. It can be calculated by taking the product of the instantaneous current and voltage over a whole number of half cycles and averaging the result, or by multiplying together the RMS voltage and current, or from the mean squared value of the voltage divided by the load resistance, and so on. All these methods give exactly the same result.

Fig. 1b shows the situation where the load is a pure reactance – it can be a capacitor or inductor depending on which of the waveforms you take to represent v and which to be i.

In either case the instantaneous power varies symmetrically about zero. On the positive parts of the curve, energy is being stored by the load. On the negative part it's being returned to the source. The load does not dissipate any energy and the mean value of the power curve is zero.

However, if we multiply the RMS voltage and current in this case we get exactly the same result as for the resistive load. One way of calculating power gives the answer zero another gives a positive value. Which is correct?

The answer is that it depends on exactly what you are trying to measure. If you want to know the average power delivered to the load (the 'real' power, measured in watts) the answer is zero. On the other hand, suppose you were to connect a capacitor directly across an AC transformer. The current flow in the windings would have just the same heating effect as for a resistive load. There is a limit to the size of capacitor you can connect directly across a transformer before it burns out! Clearly the 'real' power is not the whole story.

The effect on the transformer is measured by the product of RMS voltage and current. It is called the 'apparent' power and is measured in volt-amperes (VA) — a unit you'll no doubt have come across in transformer specifications.

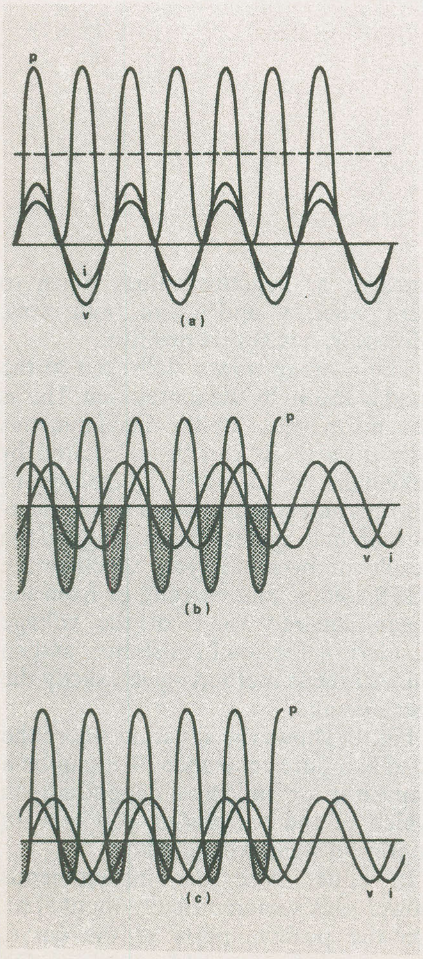


Fig. 1 Voltage, current and power waveforms for (a) a resistive load (b) a pure reactance load (c) a load with both resistive and reactive components.

Fig. 1c shows the more general situation where the load has resistive and reactive components, as in the case of a hi-fi loudspeaker. Here, the power situation is even worse — we can distinguish three different kinds.

The product of RMS voltage and current still gives the apparent power (VA), the mean of the power waveform will give the real power (watts). Now the difference between the two gives yet another power reading — the 'reactive' power, measured in 'volt-amperes reactive' (VAR).

The apparent power, then, is made up of two components: the real power delivered to the load and the reactive power which shunts backwards and forwards between load and source. So, what should a power meter measure?

The Old Bill

If we asked the electric utility, we'd get an answer without hesitation — apparent power is the one to go for. It's bigger than either of the other two and the choice can be justified by saying that even if the energy transferred from the generators to the customer's load is less than the meter reading, the 'extra' power shunted back and forth means that heavier gauge wires and bulkier transformers are needed.

The utility does indeed charge for apparent power. As a slight digression, factories are perfectly well aware that they can be charged for energy they haven't used and go to great lengths to apply power factor correction to their supplies.

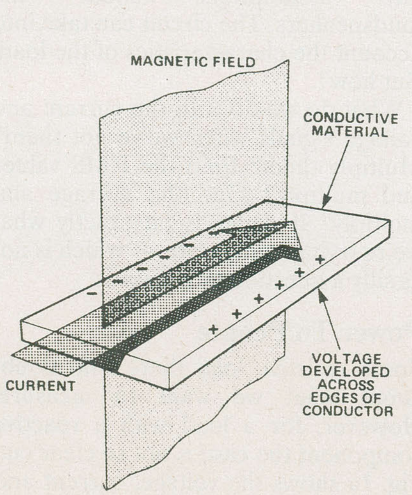


Fig. 2 The Hall effect.

The most common cause of trouble is large electric motors which have a high inductive component and the solution is to connect a whopping great capacitor across the AC — just like an amplifier's Zobel network but on a much, much larger scale.

The result is that the factory appears more like a pure resistance to the power supply and the reactive power circulates between the capacitor and the motors.

Unlikely as it sounds, this measure will often give a considerable reduction in the electricity bills.

I should point out that the capacitors used are not the type you buy from your corner shop. They have to withstand continuous AC voltage and huge currents and are therefore very costly and bulky. Four household supplies it just isn't worth the time and effort. Also, since different gadgets are being turned on and off at various times, there's no sensible way to compensate for them.

To return to the hi-fi power meter, the most sensible thing to measure seems to be the power that is actually used by your loudspeakers — the real power. It may not be quite so flattering to your amplifier as apparent power but it's a realistic indication of the power used by the loudspeakers. How much of this actually gets converted to sound rather than heat is a matter between you and the hi-fi manufacturer.

The method for calculating real power applies to any old waveform, and this is:

The voltage and current signals are continuously multiplied to give the instantaneous power, then the resulting power waveform is average over a number of cycles to give the mean power.

The four quadrant multiplier is needed because the areas below zero on the power waveform represent energy returned to the amplifier to be dissipated in the output transistors. This must be subtracted from the area above zero which represents the total energy supplied (some of which is returned). This will all be taken care of by a four quadrant multiplier and suitable averaging circuit.

Acceptability

Having decided what we want to measure and how to go about it, the next question is acceptability. What will make hi-fi enthusiasts feel happy to connect to their amplifiers? My modest aim has been to produce a circuit which will introduce no distortion whatsoever into top-flight hi-fi equipment. Anybody who will be happy with this approach should be more than satisfied with the circuit.

Tapping a voltage reading from the amplifier output presents no particular problem. The main question is how to derive a suitable current signal. Introducing a resistor into one of the speaker leads is the usual solution. However, although the disturbance caused by a 0.1 ohm resistor would be negligible in all but the very finest equipment, a better approach should be sought if possible.

My first thought on the subject was to use a Hall effect device to measure the current. If you are not familiar with the Hall effect, Fig. 2 shows the general idea. The rectangle is a strip of some kind of conductive material. A magnetic field at right angles to the strip will produce a voltage at the edges.

The effect is exhibited by any conductor whatsoever, even the track on a PCB but is generally so small as to be unmeasurable. Some semiconductor materials produce relatively high voltages for fairly modest flux densities and can be obtained in IC form, often with internal amplifiers.

One of the loudspeaker leads running alongside such an IC would have been the ideal way to derive a current signal without disturbing the audio signal. Unfortunately, the devices I tried were all far too noisy and insensitive to obtain clean signal, so it was back to the drawing board.

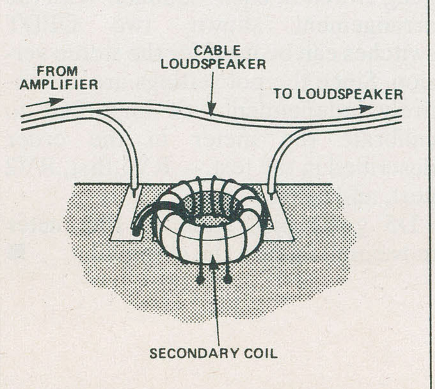


Fig. 3 The current transformer approach.

The Long And Winding Road

The solution that eventually produced excellent results was a current transformer (Fig. 3). One of the speaker leads is broken and forms a half turn around a suitable toroid via a single hoop of wire. The secondary coil is wound around the toroid giving a step-down in current of about 200:1.

For best performance (and to avoid reflecting the slightest suspension of anything unwanted back into the primary circuit) the transformer must be terminated with a very small resistance — a fraction of an ohm if possible. Since high performance current buffers don't exist in IC form, this approach leads to some interesting problems, but space won't allow me to elaborate at this time.

Budget Power Meter

The circuit of the budget power meter is shown in Fig. 4. It depends entirely on the voltage for the readings, and draws a small current from the amplifier output to drive the meter. The rectifiers are used to produce an approximation to a square law, and also to rectify the signal for the meter. Two different speaker impedances can be selected by SW1 and two different power ranges (0-10W and 0-100W) by SW2.

The component overlay for the project is shown in Fig. 5. There is so little on the PCB that it should be almost impossible to make a mistake. If you use the specified meters, the PCBs can be mounted on the back. Otherwise, they can be fixed to the case by means of the screw holes.

The meters can be back-lit, but this means giving the meter a power supply it would not otherwise need, so it's up to you whether or not you think it worthwhile. Incandescent bulbs will give better result than LEDs. You can probably get away with using a small transformer driving a few bulbs in series.

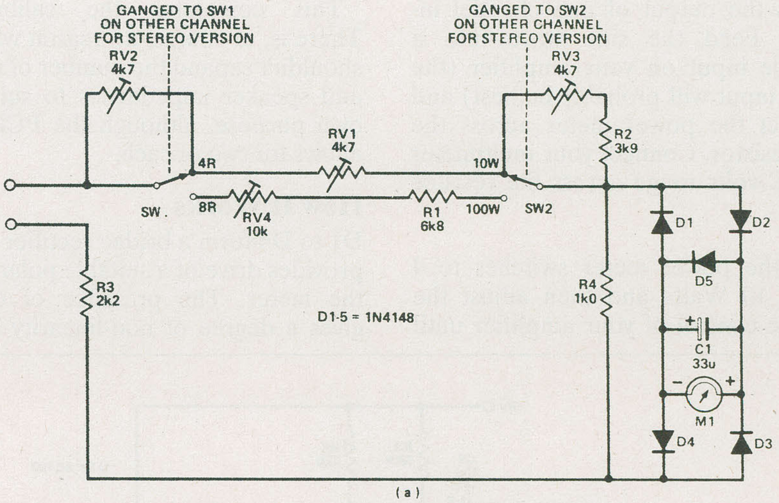
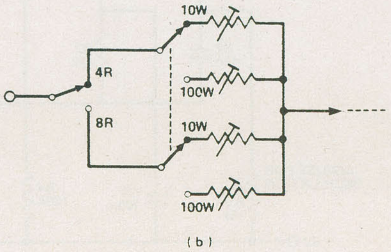


Fig 4. (a) the circuit diagram of the budget power meter



(b) alternative switching arrangement for totally independent range adjustment.

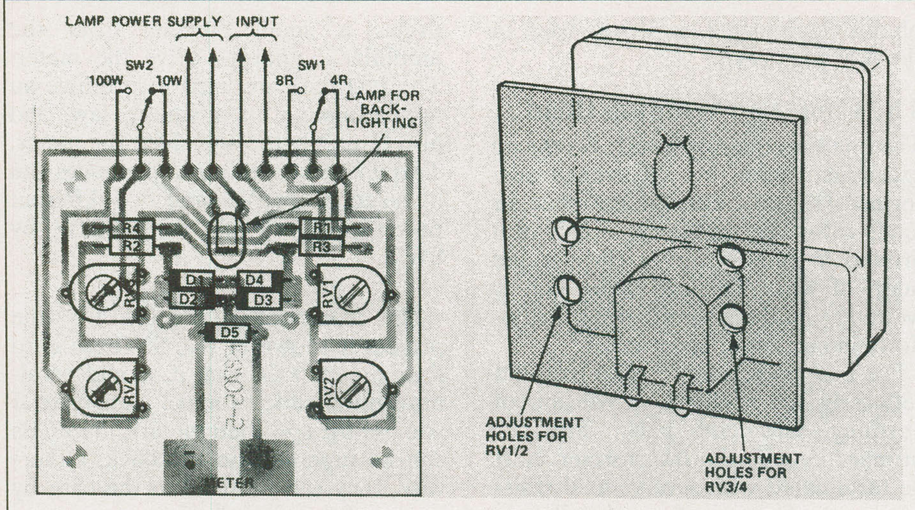

LAMP POWER SUPPLY
INPUT
SW2
100W
10W
SW1
8R
4R
LAMP FOR BACK-LIGHTING
R4
R2
R1
R3
D1
D4
D2
D3
D5
RV4
RV1
RV2
RV3
E8005-5
METER
ADJUSTMENT HOLES FOR RV1/2
ADJUSTMENT HOLES FOR RV3/4

Fig. 5 The component overlay for the budget power meter.

Parts List

Resistors

R1	6k8
R2	3k9
R3	2k2
R4	1k0
RV1,2,3	4k7
RV4	10k

Capacitors

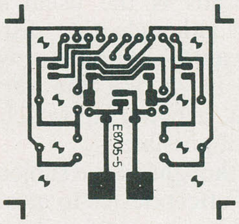
C1	33uF 16V elect.

Semiconductors

D1-D5	1N4148

Miscellaneous

PCB; any fairly sensitive current meter movement, scaled 0 - 10; optional components for backlighting: bulbs, transformer; and case.



The PCB pattern for the power meter

Calibration

You will need a sine wave generator and a multimeter. If you haven't got a signal generator, the circuit of Fig. 6 will do the trick. If you haven't got a multimeter, go out and buy one! (How on earth do you manage to test your circuits without it?).

Disconnect the speakers from your amplifier and connect a 1K0 resistor across the output of one channel instead. Feed the sine wave into a suitable input on your amplifier (the AUX input will probably be best) and connect the power meter across the 1K0 resistor. Connect your multimeter on AC volts range across the resistor too.

Set the power meter switches to 4 ohms, 10 Watts and then adjust the volume control of your amplifier until the meter reads 6.3V. Adjust RV1 until the power meter reads 10W exactly.

Set the power meter to 8 ohms, and adjust the amplifier volume control until the meter reads 8.9V. Adjust RV2 until the meter reads 10W.

For 4 ohms, 100W, set the multimeter to 28.3V and the power meter to a reading of 10 (which once again represents 100W).

This completes the calibration. There is, of course, no reason why you shouldn't expand the number of ranges and speaker impedances to suit your own purpose, although the PCB only allows for two of each.

How It Works

D1 to D4 form a bridge rectifier which provides drive of a suitable polarity for the meter. The presence of diodes gives a degree of non-linearity to the current to voltage relationship with a little imagination we can pretend it's something like a square law relationship.

To make the best of the diode characteristics, the more sensitive the meter movement the better. If you choose a more sensitive type, you should reduce the value of R4 and leave all other components values the same.

The network of resistors around SW1 and SW2 simply pad the voltage divided to cope with different input ranges. The arrangement looks unnecessarily complicated but was devised to avoid the need for a double gang switch in each channel. With the arrangement shown, two DPDT switches can be used for the stereo version. Since the pot settings are not entirely independent, it's important to calibrate the meter in the order described in the text — RV1 first, RV2 next, and so on.

D5 gives protection to the meter movement against the overload. ■

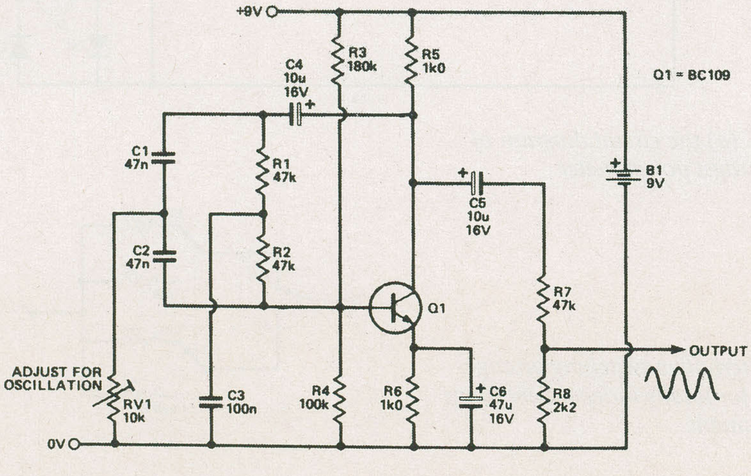

+9V
R3 180k
R5 1k0
C4 10u 16V
Q1 = BC109
C1 47n
R1 47k
C5 10u 16V
B1 9V
C2 47n
R2 47k
R7 47k
Q1
OUTPUT
ADJUST FOR OSCILLATION
RV1 10k
C3 100n
R4 100k
R6 1k0
C6 47u 16V
R8 2k2
0V

Fig. 6 A simple signal generator circuit for calibrating the power meter.

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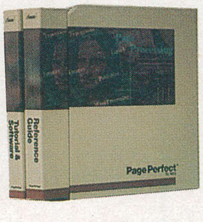

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Car Alarm

continued from page 47

If an attempt is made to remove the radio or other protected items, the siren sounds instantly. This is done by using the latches IC1a, IC1b. Pins 11 and 12 of the alarm are held low by connecting them to the chassis of the radio or connecting them to 0 volts via the loops described earlier. If one of these two connections is removed either Q2 or Q3 is turned on by their bias resistors R5, R9 respectively. This in turn puts a low on IC2d pins 12 or 13 which causes the output pin 11 to go high. This low to high transition is used to clock the two latches IC1a, b. The circuit now follows the same count routine as before except that the siren latch has already been set eliminating the 128 clock pulse delay, but it is turned off in the same way after 2048 clock pulses.

The timings rely on the oscillator running at about 25Hz. The speed of this oscillator can be increased by reducing R11 and slowed down by increasing its value. However, do not reduce below 15k as this may damage the IC.

Installation

Fig 2. shows the overlay for the alarm PCB. Construction should cause no particular problems.

Before fitting the alarm, it should be fully tested on the bench using a power supply and simple switches on pins 6, 7, 11, 12. To simulate the car courtesy light, connect a 47k resistor between pins 1 and 6 of the alarm. This will hold off Q1 unless turned on by a low on pins 6 or 7.

When happy that the alarm works under all possible valid switch configurations it should be considered ready to fit. As it is going to stay in the car (which can be a hostile environment) the PCB should be fully cleaned and sprayed with a PCB protective varnish to prevent the copper tracks from being eaten away by dampness.

Test all points of the car's electrical system that are to be used with a meter to check they perform as expected. It is a good idea to disconnect the positive side of the battery while fitting the alarm to prevent any accidental shorts. ■

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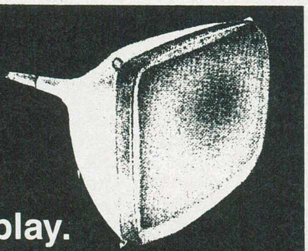

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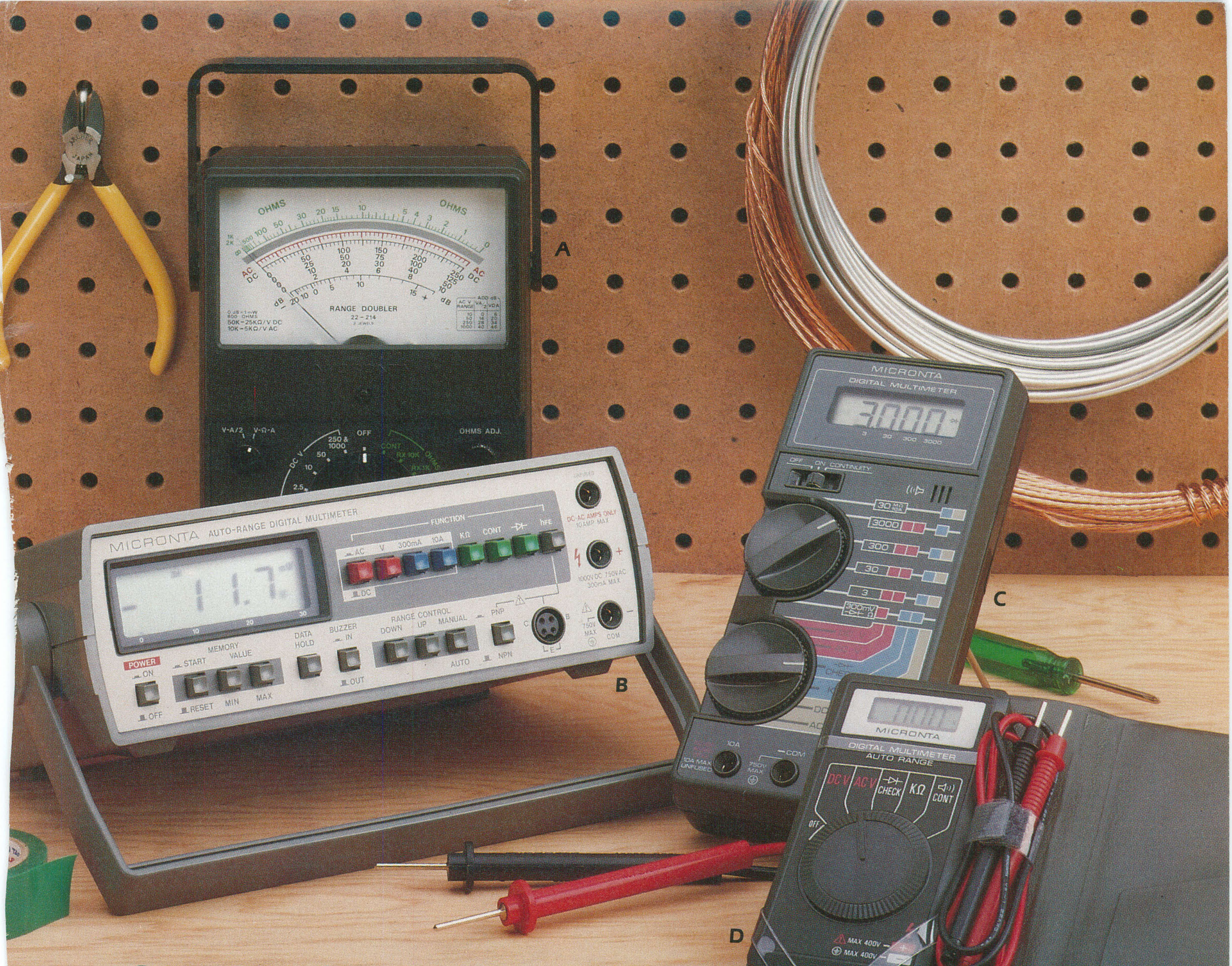

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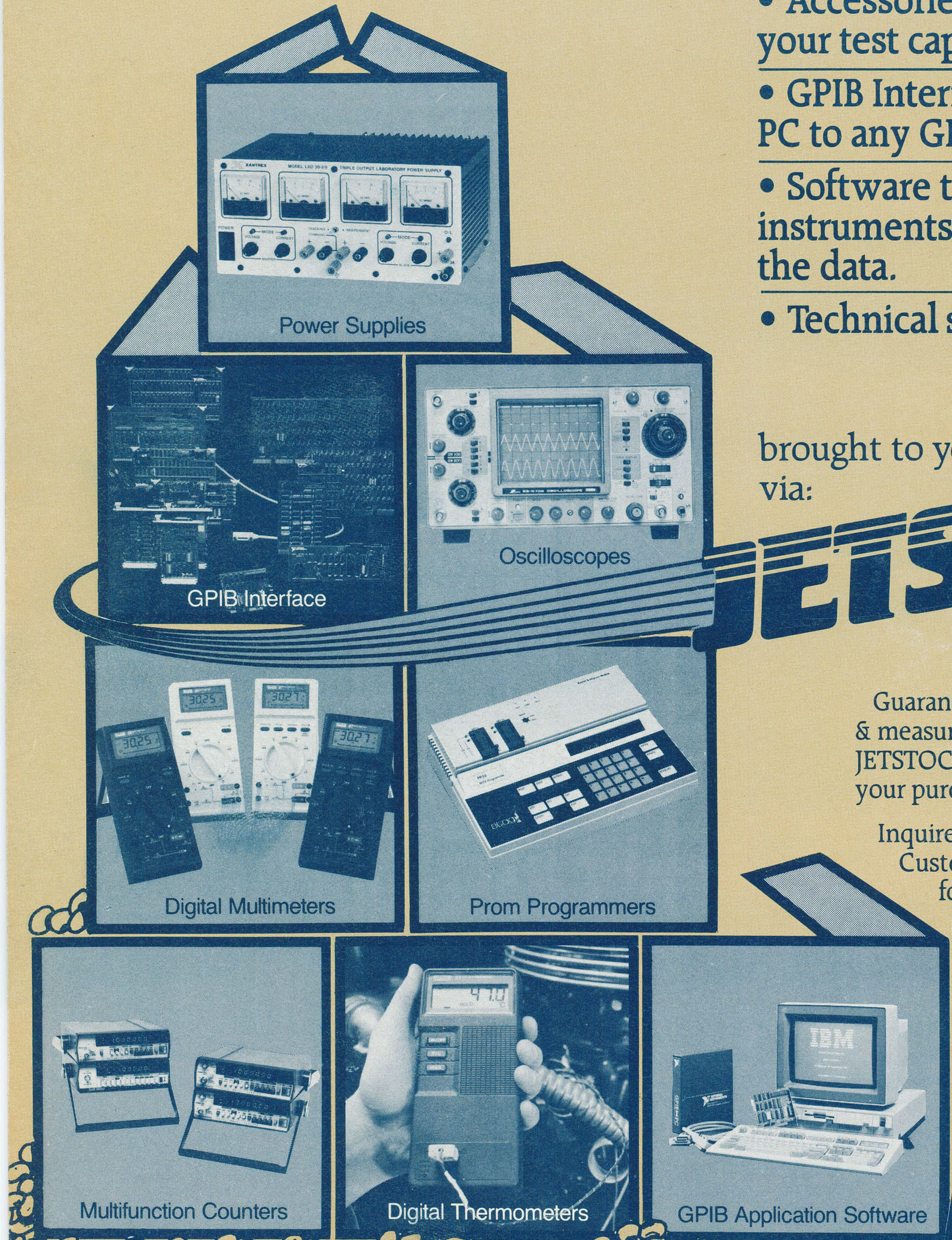
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